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Dietary Intake and Executive Function in Youth and Emerging Adulthood: Environmental Correlates and Developmental Considerations

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LOYOLA UNIVERSITY CHICAGO

DIETARY INTAKE AND EXECUTIVE FUNCTION IN YOUTH AND EMERGING ADULTHOOD: ENVIRONMENTAL CORRELATES AND DEVELOPMENTAL CONSIDERATIONS

A DISSERTATION SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

PROGRAM IN CLINICAL PSYCHOLOGY

BY

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CHICAGO, IL

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Dedicated to the Best Cohort Ever.
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ABSTRACT

Obesity is a major public health concern impacting one in five young people in the U.S., and research suggests that consumption of high calorie, low nutrient foods may play a role in weight gain. Executive function (EF) has emerged as a factor that may play a role in dietary intake across youth development. Although biopsychosocial models of obesity emphasize the importance of identifying individual and environmental influences that may be associated with poor dietary intake, empirical research in this area is lacking. Therefore, the current set of studies seeks to (1) systematically review the literature on the association between EF and dietary intake across youth, from a developmental perspective, (2) use an ecological systems approach to investigate mechanisms underlying EF and dietary intake during the summertime, and (3) evaluate food marketing as an environmental factor that may influence the relation between EF and dietary intake, especially for vulnerable populations, such as those with disordered eating. Overall, findings suggest that the relation between EF and dietary intake in youth is complex and is likely influenced by individual factors, highlighting the importance of identifying individuals who are more responsive to the food environment to help design more effective obesity intervention and prevention programs.
CHAPTER ONE
INTRODUCTION

In the last two decades, obesity has emerged as a major public health concern. Estimates suggest that among youth ages 2-19, obesity rates are close to 20% in the U.S. (Skinner, Ravanbakht, Skelton, Perrin, & Armstrong, 2018). Childhood obesity has been linked to a range of health conditions, such as heart disease and diabetes (Freedman, Mei, Srinivasan, Berenson, & Dietz, 2007), and researchers estimate that it also carries a significant economic impact due to the direct medical costs associated with the condition (Finkelstein, Graham, & Malhotra, 2014). These problems are compounded considering that overweight children are likely to remain overweight as adolescents, and overweight adolescents are likely to remain overweight as adults (Singh, Mulder, Twisk, Van Mechelen, & Chinapaw, 2008). Because of this, public health advocates argue that obesity prevention and intervention efforts should occur across developmental stages, from early childhood to young adulthood (Stice, Shaw, & Marti, 2006).

Efforts to both prevent and treat obesity have led researchers to examine the complex interplay of factors that lead to increased weight gain. On a basic level, weight gain results from a caloric imbalance, where consumption exceeds expenditure (Caballero, 2007). Much of the prevailing literature has used an ecological systems approach, taking into account multiple levels of influences that may contribute interdependently to this imbalance (Davison & Birch, 2001). However, there is considerable evidence to suggest that calories are much easier to consume than they are to burn (Bleich, Barry, Gary-Webb, & Herring, 2014; Dowray, Swartz, Braxton, &
Viera, 2013). Because of this, understanding the factors that are associated with dietary intake, especially of high-calorie, low nutrient foods, is key to understanding weight gain.

**Dietary Intake across Youth**

Research shows that youth in the U.S. do not meet even half of the recommended daily values of vegetables, whole grains, or fatty acids (found in many green vegetables, nuts, and oils) (Banfield, Liu, Davis, Chang, & Frazier-Wood, 2016). Furthermore, youth consistently fall short of recommended USDA Healthy Eating Index scores, which capture overall consumption of both healthy and unhealthy foods (Guenther et al., 2013). Indeed, estimates suggest that half of all foods that youth consume represent empty calories from solid fats, alcohols, and added sugars, which have been linked to weight gain (Banfield et al., 2016; Guenther et al., 2013; Morenga, Mallard, & Mann, 2013).

Although problematic across age ranges, there is evidence to suggest that overall dietary quality decreases with age during childhood, and continues to decline through the late teen years (Banfield et al., 2016). This decline appears to continue during emerging adulthood, the period usually defined as ages 18-25 (Nelson, Story, Larson, Neumark-Sztainer, & Lytle, 2008). Research shows that emerging adults eat more fast food and drink more sugar sweetened beverages (SSBs) than any other age group (Nielsen & Popkin, 2004; Paeratakul, Ferdinand, Champagne, Ryan, & Bray, 2003), and they consume fewer fruits and vegetables than they did when they were children (Demory-Luce et al., 2004). Furthermore, it appears that the dietary patterns established in young adulthood are likely pervasive throughout adulthood (Dunn, Liu, Greenland, Hilner, & Jacobs, 2000). Thus, emerging adulthood may also be a particularly important time for investigating factors that are associated with healthy dietary intake patterns.
The Role of Executive Function

Given that dietary intake appears to worsen with age, it is important to consider the dietary changes seen across youth and emerging adulthood in the context of overall development. From an environmental perspective, children are likely to gain more autonomy as they get older, including more responsibility for choosing and acquiring the foods that they eat (Bassett, Chapman, & Beagan, 2008). Psychologically, this increase in autonomy corresponds with the development of the ability to exercise the high-level cognitive processes that control goal-directed behavior, also known as executive function (EF). One widely accepted theory of EF, the “unity and diversity” model, considers EF to be one single construct conceptualized in multiple domains including: inhibition (e.g., suppressing a dominant impulse in favor of a different behavior), working memory (e.g., ability to update working memory to adapt to new tasks), and cognitive flexibility/task switching (e.g., shifting from one task to another) (Miyake et al., 2000). Research suggests that EFs comprise related but distinct domains (Friedman & Miyake, 2017). Evidence for the unity and diversity model has been found in children as young as four (Senn, Espy, & Kaufmann, 2004) and support for the model continues throughout elementary school and adolescence (Best & Miller, 2010; Lehto, Junjärvi, Kooistra, & Pulkkinen, 2003). Although the domains of EF develop at slightly different rates (Best & Miller, 2010), across domains the key periods of development include the preschool years (age 4), the elementary years (ages 7-9), the early adolescent years (ages 11-13), and the emerging adult years (ages 18-25) (Anderson, 2002). Interestingly, these are also important periods in the development of both healthy and unhealthy dietary intake patterns (Banfield et al., 2016), which supports the hypothesis that EF and dietary intake may be related to one another.
Much of the existing literature on EF and dietary intake has conceptualized dietary intake as a predictor of EF, given evidence that even small changes in the gut microbiome may impact individual variability in cognitive abilities such as learning and memory (Davidson, Cooke, Johnson, & Quinn, 2018). However, recent research has begun to investigate the inverse relation, treating EF as a predictor of dietary intake. As such, in a review of the association between EF and dietary choices (including both adhering to a diet and experiencing dietary lapses) across the lifespan, Dohle and colleagues (2017) theorize that: (1) planning meals, (2) the choices to avoid and select certain foods, and (3) the ability to resist against strong urges to eat foods that are highly palatable, but also unhealthy, are all examples of the ways in which EF is necessary for making healthy food choices. Conversely, poor EF has been associated with both unhealthy eating and overweight/obesity across the lifespan, including in children and adolescents (Reinert, Po’e, & Barkin, 2013; Smith, Hay, Campbell, & Trollor, 2011). These findings suggest that it is important to consider the bi-directional nature of the relation between dietary intake and EF.

Despite evidence for a probable link between EF and dietary intake, much of the existing literature has failed to consider the impact that normative developmental changes in EF may have on an individual’s food consumption. Without consideration of such changes, it is difficult to determine how EF may be differentially associated with dietary intake across the developmental spectrum.

**Environmental Influences of Executive Function**

In addition to appreciating the developmental progressions in EF that may influence its relation with dietary intake, it is also important to consider the environmental factors that may play a role. Although youth encounter many environmental influences that have the potential to shape their behavior, there is evidence to suggest that unstructured time and exposure to food
marketing may each play a key role. Therefore, it is crucial to investigate the mechanisms that may link both structure and food marketing to dietary intake and EF.

Research conducted on summertime, a recurring period of unstructured time, has shown that youth are more likely to gain weight and eat less healthfully during the summer months (Baranowski et al., 2013; Tovar et al., 2010). However, few studies have examined the role that EF may play in relation to these findings. EF may be necessary to resist eating unhealthy, but highly palatable foods, and make the necessary plans to acquire and prepare healthier options (Riggs, Spruijt-Metz, Chou, & Pentz, 2012). This may be particularly important during the unstructured summer months when youth are out of school and have less access to programs such as school lunch. However, no studies to date have examined whether individual differences in EF, which may be more apparent in the context of less structure, may be partially responsible for the obesogenic behaviors often seen during this period. Additionally, few studies have examined summertime structure in the context of socioeconomic status. This is important given that low-income youth may be more likely to experience unstructured time than youth with the resources to attend summer camps and participate in other structured activities (Cornelli Sanderson & Richards, 2010).

In addition to unstructured time, another environmental factor that should be considered when evaluating EF and dietary intake is food marketing. Estimates suggest that food companies spend over $1 billion on marketing to children alone (Federal Trade Commission (FTC), 2012), primarily for high calorie, low nutrient foods (Powell, Szcypka, Chaloupka, & Braunschweig, 2011). There is evidence to suggest that the impact of food marketing can be seen throughout childhood, with children as young as four showing a marked preference for branded foods over non-branded foods (Robinson, Borzekowski, Matheson, & Kraemer, 2007). Marketing then
remains pervasive throughout youth and into emerging adulthood. Indeed, the 18-24 age range may be a particular time of targeted marketing (Nelson et al., 2008). Nelson and colleagues outlined several fast food companies, including Taco Bell, Hardee’s, and Burger King that have won awards for targeted campaigns seeking to increase brand recognition and consumption in males ages 18-24. This is particularly problematic given increasing evidence that exposure to food marketing not only influences consumption of the product being advertised, but also increases consumption of other highly palatable, and often unhealthy, foods (Harris, Bargh, & Brownwell, 2009).

In addition to research suggesting that environmental influences, like food marketing, may influence EF and dietary intake, there is also evidence that some individuals may be particularly susceptible to the role that these environmental influences play. Specifically, individuals with disordered eating may be at risk. Limited research from experimental studies has shown that individuals with higher levels of dietary restraint, (i.e., those who attempt to exercise high levels of cognitive control over what they eat instead of relying on physical hunger cues), may be more susceptible to eating after watching television commercials than those with lower levels of dietary restraint (Harris, Bargh et al., 2009). Transdiagnostic theories of eating disorders emphasize that one common factor that characterizes many eating disorders is an overemphasis of the importance of shape and weight (Fairburn, Cooper, & Shafran, 2003). This may manifest through dietary restraint and subsequent impulsive behavior in response to lapses in dietary restraint (Fairburn et al., 2003). Therefore, it is possible that individuals with patterns of disordered eating, may be more susceptible to food marketing, but few studies have tested this hypothesis.
Overall, despite considerable evidence for a relation between food marketing and dietary intake, which may be stronger for some individuals and under certain environmental influences, little research has examined the mechanisms behind that relation. Research has shown that food images elicit similar amounts of craving and reactivity as real food (Boswell & Kober, 2016). If this is the case, it is possible that EF may also play a role in an individual’s reaction to food marketing, such that the EF skills needed to resist against the messages presented in food advertisements may be similar to the EF skills needed to resist unhealthy foods in real life. Given the pervasive nature of food marketing, it is possible that the present food environment requires consistent exercise of EF. Specifically, it may require constant exercise of inhibition, the practice of suppressing a dominant response in favor of a goal-directed response. Previous research suggests that exercising inhibition in one domain may impact an individual’s success at exercising inhibition in another domain (Muraven, Tice, & Baumeister, 1998). Thus, it is possible that the inhibition required to resist against the messages presented in food advertisements may impact later tasks requiring inhibition, like making healthy food choices. However, no studies to date have tested this hypothesis, representing a gap in the literature that may help to explain the link between exposure to food marketing and the subsequent consumption of energy dense, nutrient poor foods.

In conclusion, the current evidence linking EF to dietary intake has been established, but there are several gaps in the literature that make this relation difficult to contextualize. These gaps include lack of emphasis on the developmental course of EF in the interpretation of its relation to dietary intake as well as consideration of environmental factors that may influence EF, dietary intake, or the association between the two. Finally, individual differences, such as disordered eating, may further complicate the relation between the food environment, EF, and
dietary intake, and thus should also be examined. Figure 1 presents a proposed model of the interplay between EF, food marketing, and dietary intake.

**Overview of Current Proposal and Studies**

Given gaps in the literature on dietary intake, EF, and the environmental factors that influence the two variables, the current set of studies seeks to elucidate these relations across youth and emerging adulthood (see Figure 1). The first study, “Executive Function and Dietary Intake in Children: A Systematic Review of the Literature,” published in *Appetite*, reviews the literature on EF and dietary intake in children under 18 from a developmental perspective (Egbert, Creber, & Loren, & Bohnert, 2019). This review summarizes the literature examining relations between EF and dietary intake with a particular focus on how developmental changes in EF relate to dietary intake patterns. It also conceptualizes multiple domains of EF, including inhibition, working memory, and cognitive flexibility/task switching to consider the relation between EF and dietary intake from a bi-directional perspective. Finally, the review considers how interventions to either alter dietary intake and improve EF or alter EF and improve dietary intake may help to further explain the relation between the two.

The second study, “The Heat is on: A Mixed-Method Examination of Eating Behavior and Executive Functions among Low Income Minority Girls during Summertime” published in the *Journal of Early Adolescence*, uses an ecological systems approach to investigate the mechanisms underlying dietary intake during the summertime in a sample of low-income urban minority girls (Egbert et al., 2018). This study evaluates the relation between dietary intake and EF while taking into account environmental factors, including the increase in unstructured time that often occurs during the summer. Drawing from a sample of girls enrolled in a community-based summer program, this multi-method study evaluates 79 girls using neuropsychological
measures to assess EF, 24-hour dietary recalls to assess dietary intake, and accelerometers to measure sleep onset and duration. Additionally, this study includes qualitative interviews from a subset of 14 parents to capture information regarding changes in family routines and scheduling at the beginning of the summer. This study helps to contextualize the relation between poor EF and unhealthy dietary by considering environmental factors. It provides evidence that individual differences in EF may be particularly important during a period of unstructured time, such as the summer.

Figure 1. Model of Interplay between Executive Function, Food Marketing, and Dietary Intake

Finally, the third study “The Impact of Viewing and Responding to Unhealthy Food Marketing on Inhibition in Adolescents and Emerging Adults: Disordered Eating as a Moderator” extends the research on food marketing as a contextual factor that may influence dietary intake. Using a within-subjects design, this study serves as a preliminary investigation of inhibition as a mechanism behind the relation between food marketing and unhealthy dietary
intake by assessing the impact of watching and responding to television commercials on subsequent inhibition as measured by: (1) an adapted Stroop-task, (2) a food-specific stop-signal task, and (3) a lab-based food task. Additionally, this study examined whether individual differences moderated the relation between food marketing and inhibition. This mixed-methods study extends the literature on EF and dietary intake in youth by investigating all of these constructs specifically in emerging adults, individuals who are treated as adults in many contexts but whose decision-making abilities are not fully developed (Best & Miller, 2010). Emerging adults are often responsible for independently making food choices in the midst of significant life transitions, such as living on their own for the first time or beginning college, that may influence both food preference and accessibility (Nelson et al., 2008). Therefore, it is important to understand how food marketing may impact this population in light of their ongoing development of inhibition skills.
CHAPTER TWO

EXECUTIVE FUNCTION AND DIETARY INTAKE IN YOUTH:
A SYSTEMATIC REVIEW OF THE LITERATURE

Consumption of high amounts of energy dense, nutrient poor foods has been linked to weight gain, and easy access to these foods makes the current food environment particularly problematic. Although the factors leading to weight gain are multifaceted, executive function (EF), the cognitive processes involved in effortful and goal-directed behavior (Best, 2010), has emerged as a potential individual-level contributing factor to weight gain. Indeed, results from two reviews have demonstrated that poor EF is associated with weight gain and obesity rates among youth (Pearce, Leonhardt, & Vaidya, 2018; Smith et al., 2011). To explain this association, obesity researchers have theorized that EF may help to explain some aspects of non-homeostatic eating (i.e., eating beyond the need for calorie repletion), particularly individual differences in the ability to resist unhealthy foods (Hall, 2016). In contrast, research from other disciplines focuses on the contributions of less nutritious dietary intake on poor EF (Cohen, Gorski, Gruber, Kurodziel, & Rimm, 2016). Thus, a systematic investigation that includes both types of research questions can inform understanding of potential bi-directional associations between EF and dietary intake addressing a notable gap in the literature.

Executive Function across Development

One of the most widely accepted theories of EF, the “unity and diversity” model, considers EF to be one single construct conceptualized in multiple domains including: inhibition

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(e.g., suppressing a dominant impulse in favor of a different behavior), working memory (e.g., ability to update working memory to adapt to new tasks), and cognitive flexibility/task switching (e.g., shifting from one task to another) (Miyake et al., 2000). There has been considerable research to support the hypothesis that EFs comprise related but distinct domains (Friedman & Miyake, 2017). Evidence for the unity and diversity model has been found in children as young as four (Senn et al., 2004) and support for the model increases in elementary and adolescent youth (Best & Miller, 2010; Lehto et al., 2003). In addition, although EF has been correlated with intelligence, there is also evidence to suggest that it represents a set of processes that are distinct from general intelligence (Friedman & Miyake, 2017).

Drawing on the unity and diversity model, findings from developmental literature demonstrate that the three domains of EF develop at different rates throughout childhood and adolescence. For example, research suggests that inhibition develops rapidly during the preschool years. Specifically, by three years of age, children have developed the ability to inhibit instinctual responses, and there is evidence to suggest that notable gains continue to occur through 6-7 years of age (Anderson, 2002). By elementary school age, inhibition appears to be well-developed across tasks (Nigg, 2000). Importantly, problems with disinhibition (e.g., ADHD) are most often identified during this age. After this period, inhibition then continues to develop during emerging adulthood, such that youth ages 14-17 exhibit slower, more effortful performance on a stop-signal task as compared to the performance of adults over age 25 (Vidal, Mills, Pang, & Taylor, 2012).

Similar to inhibition, both working memory and cognitive flexibility also improve over the course of development. There is evidence to suggest that working memory capacity is developed in the first years of life, before a child enters school, and continues to develop
throughout middle childhood (Garon, Bryson, & Smith, 2008). Likewise, cognitive flexibility also begins to develop during the preschool years, develops even more rapidly between ages 7-9, and continues to develop throughout adolescence (Anderson, 2002). Overall, the three domains of EF all improve over the course of development, which is important to consider when assessing EF’s relation to other behaviors, such as dietary intake.

**EF and Dietary Intake across Development**

Although it is clear that developmental shifts in EF occur throughout youth, much of the existing research from the obesity literature fails to distinguish between children of different age groups, making it difficult to understand whether the relation between EF and dietary intake differs across development. A recent narrative review by Dohle and colleagues (2017) investigated EF (i.e., inhibition, working memory, and cognitive flexibility) as a possible predictor of both healthy and unhealthy eating behaviors across the lifespan. The authors concluded that the association between inhibition and unhealthy dietary intake was supported by existing research but found little evidence for an association between inhibition and healthy dietary intake. Mixed results were reported for working memory and cognitive flexibility regardless of the type of eating behavior (healthy or unhealthy) (Dohle et al., 2017). However, the authors combined results from both the child and adult literature, which does not allow for developmental considerations regarding the relation between EF and dietary intake. Additionally, despite the authors’ conceptualization of EF as a predictor of dietary intake, the review did not distinguish between findings drawn from cross-sectional studies and those found in longitudinal studies, making it difficult to draw conclusions about directionality. Furthermore, the review included a wide range of studies that measured different components of eating behaviors. Because of this, although the review makes important conclusions about the relation between EF
and dietary intake, it is difficult to disentangle the role that EF plays in how an individual eats (e.g., restrained eating, loss of control eating, eating in the absence of hunger) from its role in what an individual eats (e.g., fruits and vegetables, junk food, sugar sweetened beverages). This distinction is important to understand the mechanisms underlying the role of EF in dietary intake and obesity.

Conceptual challenges also exist in understanding the evidence that, over time, dietary intake may influence EF. Evidence from animal models suggests that changes in the gut microbiome, which is heavily influenced by dietary intake (Singh et al., 2017), may impact cognitive and neural functioning (Davidson et al., 2018), lending support to the premise that dietary intake can affect EF. Much of the longitudinal research on the influence of dietary intake on EF in children has focused on the importance of breastfeeding on cognitive development (Victora et al., 2016), but there has been less longitudinal research on associations between dietary intake and EF in children who are no longer breastfeeding. A recent review by Cohen and colleagues (2016) reported that greater consumption of healthy foods was positively associated with cognitive functioning, including EF, and that consumption of unhealthy foods was inversely associated with cognitive functioning. However, most studies in the review were cross-sectional, making it difficult to understand directionality, and the longitudinal studies included in the review only considered cognitive functioning as a predictor of dietary intake rather than the inverse relation.

Additional evidence describing the relation between EF and dietary intake comes from intervention studies that have sought to clarify whether one may be improved by changing the other. The cognitive implications of interventions seeking to improve dietary intake have been widely researched, but most of these studies have focused on the impact of eating breakfast on
academic and cognitive performance and the effect of micronutrient supplementation on intelligence in children with nutritional deficiencies. Although there is evidence that both of types of interventions have some success (Adolphus, Lawton, Champ, & Dye, 2016; Lam & Lawlis, 2017), less is known about interventions seeking to alter aspects of dietary intake other than breakfast consumption among typically-developing youth. More recently, research from the obesity literature has begun to test interventions seeking to “train” EF in order to treat obesity. A recent review by Jones and colleagues (2018) found mixed evidence for the effectiveness of EF training interventions. Additionally, many of the interventions did not evaluate long term dietary intake as an outcome but instead investigated effectiveness only by measuring dietary intake in the lab shortly after the intervention (Jones, Hardman, Lawrence, & Field, 2018). These intervention studies provide a unique vantage point from which to view the association between EF and dietary intake, however they have not been included in systematic investigations of EF and dietary intake which could add considerably to our current understanding of these relations.

**Methodological Challenges across Disparate Literatures**

Across literatures and study designs there are consistent methodological challenges that further complicate interpretation of the evidence. For example, despite the compelling evidence for conceptualizing EF as a unique skill spanning multiple domains, many studies either: (1) conceptualize EF in a piecewise manner, only mentioning single components, such as inhibition, with little regard to the other domains; or (2) collapse across domains and conceptualize EF only as a broad, unitary function; or (3) utilize the term EF to describe both approaches, making interpretation of findings even more complex. Furthermore, other factors that may be associated with EF performance, such as internalizing and externalizing symptoms (Cataldo, Nobile, Lorusso, Battaglia, & Molteni, 2005; Emerson, Mollet, & Harrison, 2005), processing speed
(Mulder et al., 2011), and overall IQ (Friedman et al., 2006b) are often not taken into consideration. This lack of consistency makes it difficult to investigate the ways in which EF may be related to other constructs, such as dietary intake. Additionally, the term “EF” is often used interchangeably with cognitive functioning, which often leads to a poor definition of the intended construct, and likely includes other cognitive factors in addition to EF. Furthermore, many studies in the literature use proxy measures for cognitive functioning, such as grades or performance on standardized tests, which also do not measure EF specifically. In addition to these issues, even when EF is operationalized with specificity, there is also considerable variability among well-validated measures of EF. Such measures range from performance-based computerized-assessments to self- and parent-report questionnaires. The existence of multiple measures allows for EF to be assessed via a multi-method approach, however, this type of approach is rarely utilized.

Taken together, due to the need to integrate the current literature on EF and dietary intake, including cross-sectional, longitudinal, and intervention studies, as well as the need to account for development when considering the relation between EF and dietary intake, this systematic review sought to appraise the existing literature to investigate the relation between EF and dietary intake in children. Given these challenges, a conceptual model was developed to help contextualize the current review within the existing literature (see Figure 2). As can be seen in Figure 2, this model conceptualizes EF as a variable that is related to both dietary intake and obesity and, from a developmental perspective, becomes stronger over time. The current review describes EF using a traditional unity and diversity approach that examines each domain of EF (e.g., inhibition, working memory, and cognitive flexibility/task switching) as well as overall EF.
Bold lines represent the associations discussed within the current review.

Figure 2. Conceptual Model of the Relation between Executive Function, Dietary Intake, and Obesity

**Method**

**Data Sources**

Searches were conducted between February 2017 and March 2019 in the PubMed and PsychInfo databases for any peer-reviewed, English language studies that fit the study search criteria. As this is a relatively new topic of study, there was no limit set for year of publication for the reviewed studies. The research question for this study was “How is executive function associated with dietary intake in children and adolescents?” In order to find studies that would
help answer this question, we used the keywords such as “Executive function/Cognitive function/Self-control” and “Nutritional status/Dietary intake/Caloric intake.” A full list of search terms and syntax is available from the authors upon request. The search was further refined by using search engine settings to limit the search to include only studies of individuals between the ages of 1 and 18 years of age. Finally, any duplicate articles across the two databases were removed before beginning the review process.

**Literature Screening**

Selection of included articles occurred in three phases. In the first phase, CC and AE reviewed the abstracts for the following inclusion criteria: (i) presented original research; (ii) included human subjects between the age of 1 and 18 without known nutritional deficiencies; (iii) utilized validated measures of inhibition, working memory, or cognitive flexibility, (this included computerized tests as well as tests and questionnaires scored based on normative data); (iv) included a measure of dietary intake; (v) assessed the relation between EF and dietary intake either cross-sectionally, longitudinally, or via an intervention. Studies that evaluated the impact of eating versus fasting were not included. In the second phase, CC and AE independently reviewed the full text articles of abstracts that fulfilled inclusion criteria and of abstracts that required further determination. After independent review, any discrepancies between the authors’ recommendations for inclusion were resolved. In a third phase, we searched each of the full text articles for relevant references that may have been missed. These were screened and added if they met inclusion criteria. Next, a content abstraction form was created to highlight important information for each article included in the review, including data source, population, sample size, design, measures, analyses, and key findings. Finally, the search was repeated in March
2019, immediately prior to submission for publication, and any articles published after the initial search was conducted were added.

**Results**

Initial searches generated 5,650 abstracts to be screened. After duplicates of abstracts that appeared in multiple databases were removed, 5,530 abstracts were left for review. Of this, 5,340 abstracts were rejected for not meeting inclusion criteria (e.g., article did not present original research, did not measure dietary intake or EF, sample did not meet age criteria). After full text review, 165 abstracts were rejected, resulting in 25 total articles for inclusion. Finally, after searching full text articles for relevant references, one study was added, bringing the total to 26 articles (see Figure 3 for a detailed description of inclusion and exclusion of articles during the search process). Table 1 includes information regarding all studies included in the review, including the type of dietary intake and EF measurement used as well as the weight status and/or BMI of the sample if known. Both in Table 1 and in the text below, studies are separated by EF domain (i.e., inhibition, working memory, and cognitive flexibility/task-shifting), and then further separated by age to reflect acknowledgement of the possible impact of the natural EF development that occurs during childhood. The age ranges chosen are generally based on approximate divisions of ages in the U.S. educational system (i.e., preschool, elementary, middle school, high school), but studies including participants spanning across age ranges were also included.
5,650 records identified through database searching

5,530 records after duplicates removed

190 full-text articles assessed for eligibility

165 full-text articles excluded:
- no executive function measure (62)
- not original research (30)
- children with known nutritional deficiencies (22)
- no dietary intake measure (20)
- measured impact of fasting versus consumption (usually breakfast) (17)
- wrong age (14)

5,340 records excluded

1 article added through full-text reference screening

26 studies included in qualitative synthesis

Figure 3. Flowchart of Studies Included in Systematic Review
Table 1. Study Characteristics of Articles on the Association between Executive Function and Dietary Intake in Youth

<table>
<thead>
<tr>
<th>Reference</th>
<th>Population</th>
<th>Weight Status</th>
<th>Baseline Age (Range)</th>
<th>Sample Size</th>
<th>EF Measures</th>
<th>Dietary Intake Measures</th>
<th>Study Design</th>
<th>Dietary Intake Relation to EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levitan, RD, Rivera, J, Silveira, PP, et al. (2015)</td>
<td>Canadian</td>
<td>Mean zBMI = 0.57, SD = 1.10</td>
<td>M=48 months (N.A.)</td>
<td>193</td>
<td>Stop-Signal Task</td>
<td>Lab-Based Food Task</td>
<td>Cross-sectional</td>
<td>Negative relation between Stop-Signal Task performance and intake of carbohydrates, sugars</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>No relation between Stop-Signal Task performance and total caloric intake, intake of protein, fats</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Did not adjust for BMI, but accounted for maternal BMI and child birth weight</td>
<td></td>
</tr>
<tr>
<td>Pieper, JR, &amp; Laugero, KD (2013)</td>
<td>U.S.</td>
<td>Mean BMI %ile = 63.0, range = 8.5-98.4</td>
<td>M=4.4 years (3-6 years)</td>
<td>29</td>
<td>Flanker Task</td>
<td>Lab-Based Food Task</td>
<td>Cross-sectional</td>
<td>No relation between calories consumed (total, sweet or savory) and performance on the Flanker Task</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>Did not adjust for BMI</td>
</tr>
</tbody>
</table>
### Elementary (Ages 7-10)

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Sample Size</th>
<th>Mean Age</th>
<th>BMI %ile</th>
<th>Flanker Task</th>
<th>Food Diary</th>
<th>Study Design</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khan, NA, Raine, LB, Drollette, ES, Scudder, MR, Kramer, AF, &amp; Hillman, CH (2015)</td>
<td>U.S.</td>
<td>65</td>
<td>M=8.6 years (7-9 years)</td>
<td>65.4, SD = 3.7</td>
<td>Flanker Task</td>
<td>Food Diary (completed by child with assistance from parent)</td>
<td>Cross-sectional</td>
<td>Positive relation between Flanker task performance and dietary fiber intake, overall diet quality (i.e., Healthy Eating Index score), adjusting for BMI</td>
</tr>
<tr>
<td>Nederkoorn, C, Dassen, FCM, Franken, L, Resch, C, &amp; Houben, K (2015)</td>
<td>Netherlands</td>
<td>88</td>
<td>M=8.1 years (7-9 years)</td>
<td>zBMI = -0.068, SD = 0.93</td>
<td>Stop-Signal Task</td>
<td>Lab-Based Food Task</td>
<td>Cross-sectional</td>
<td>Negative relation between Flanker task performance and fat, cholesterol intake, adjusting for BMI</td>
</tr>
<tr>
<td>Guerrieri, R, Nederkoorn, C, &amp; Jansen, A (2008)</td>
<td>Netherlands</td>
<td>78</td>
<td>M=9.0 years (8-10 years)</td>
<td>BMI = 17.36, SD = 2.58</td>
<td>Stop-Signal Task</td>
<td>Lab-Based Food Task</td>
<td>Cross-sectional</td>
<td>No relation between Stop-Signal Task performance and caloric intake</td>
</tr>
<tr>
<td>Did not adjust for BMI, but instead looked at BMI as an outcome variable in separate analysis of association between inhibition and BMI (marginally significant).</td>
<td></td>
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</tr>
<tr>
<td>Study</td>
<td>Country</td>
<td>Sample Characteristics</td>
<td>Methodology</td>
<td>Measure of Inhibitory Control</td>
<td>Measure of Diet</td>
<td>Design</td>
<td>Findings</td>
<td>Adjusted for BMI</td>
</tr>
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<td>--------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Pentz, MA, Spruijt-Metz, D. Chou, CP, &amp; Riggs, NR (2011)</td>
<td>U.S.</td>
<td>Majority non-Caucasian</td>
<td>Not reported</td>
<td>M=9.3 years</td>
<td>Inhibit Subscale of Behavior Rating Inventory of Executive Function (BRIEF-SR; child report)</td>
<td>Longitudinal</td>
<td>Positive relation between inhibitory control problems on the BRIEF-SR and intake of “high-calorie, low nutrient” snacks (cross-sectional)</td>
<td>Did not adjust for BMI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1005</td>
<td>Food Frequency Questionnaire (completed by child)</td>
<td></td>
<td>Positive relation between inhibitory control problems on the BRIEF-SR and intake of “high-calorie, low nutrient” snacks (longitudinal/growth)</td>
<td>Did not adjust for BMI</td>
</tr>
<tr>
<td>Whyte, AR, Schafer, G, &amp; Williams CM (2016)</td>
<td>U.K.</td>
<td></td>
<td>Not reported</td>
<td>M=8.7 years (7-10 years)</td>
<td>Go/No-Go Task, Flanker Task</td>
<td>Lab-Based Food Task</td>
<td>Intervention - Cross-sectional</td>
<td>Positive relation between consumption of a wild blueberry powder drink and performance on Flanker Task.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>21</td>
<td></td>
<td></td>
<td>Positive linear relation between amount of wild blueberry powder (0mg, 15 mg, 30 mg) and performance on Flanker Task.</td>
<td>Did not adjust for BMI</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>No relation between consumption of a wild blueberry powder drink and performance on a Go/No-Go Task.</td>
<td>Did not adjust for BMI</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Country</td>
<td>Sample Size</td>
<td>Intervention</td>
<td>Device</td>
<td>Sample Description</td>
<td>Results</td>
<td></td>
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</tr>
<tr>
<td>Folkvord, F, Veling, H, &amp; Hoeken, H (2016)</td>
<td>Cross-sectional</td>
<td>Netherlands</td>
<td>Not reported</td>
<td>Go/No-Go Task</td>
<td>Lab-Based Food Task</td>
<td>Children receiving food based go/no-go task aimed at “training” inhibition ate significantly fewer calories than those who did not.</td>
<td>Did not adjust for BMI</td>
<td></td>
</tr>
<tr>
<td>Stautz, K, Pechey, R, Couturier, DL, Deary, IJ, &amp; Marteau, M. (2016)</td>
<td>Longitudinal</td>
<td>U.K.</td>
<td>M=10.0 years (7-13 years)</td>
<td>Stop Signal Task</td>
<td>Food Diary (completed by child with assistance from parent)</td>
<td>No relation between Stop-Signal Task performance and fruit and vegetable consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ames, SL, Kisbu-Sakarya, Y, Reynolds, KD, et al. (2014)</td>
<td>Cross-sectional</td>
<td>U.S., Majority Hispanic</td>
<td>M=15.84 (14-17 years)</td>
<td>Go/No-Go Task</td>
<td>Food Frequency Questionnaire (completed by child)</td>
<td>Negative relation between Go/No-Go Task performance and sweet, salty/fatty snack consumption (males).</td>
<td></td>
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</tr>
</tbody>
</table>

**Early Adolescence (Ages 10-13)**

  - U.K.
  - Mean BMI = 20.38, SD = 3.52
  - M=10.0 years (7-13 years)
  - Stop Signal Task
  - Food Diary (completed by child with assistance from parent)

**Late Adolescence (Ages 14-17)**

  - U.S., Majority Hispanic
  - Males – 55.2% healthy weight, 37.9 over weight/obese;
  - Females – 56.8% healthy weight, 37.8% over weight/obese
  - M=15.84 (14-17 years)
  - Go/No-Go Task
  - Food Frequency Questionnaire (completed by child)
<table>
<thead>
<tr>
<th>Authors</th>
<th>Location</th>
<th>Race</th>
<th>Age</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ames, SL, Wurpts, IC,</td>
<td>U.S.</td>
<td>Majority Hispanic</td>
<td>M= 16 years</td>
<td>Inhibition Survey for recruitment; Go/No-Go Task for intervention; Implementation Intentions for intervention; Self-Ordered Point Task for working memory moderation analyses</td>
</tr>
<tr>
<td>Pike, J, MacKinnon, DP,</td>
<td></td>
<td></td>
<td></td>
<td>Food Frequency Questionnaire (completed by child); Lab-Based Food Task</td>
</tr>
<tr>
<td>Reynolds, KR, &amp; Stacy,</td>
<td></td>
<td></td>
<td></td>
<td>Intervention - Cross-sectional Main analyses –</td>
</tr>
<tr>
<td>AW (2016)</td>
<td></td>
<td></td>
<td></td>
<td>No relation between sugar sweetened beverage (SSB) Go/No-Go Task training and number of calories consumed, grams of sugar consumed, or type of beverages consumed in the lab.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No relation between SSB related Implementation Intentions and, grams of sugar consumed, or type of beverages consumed in the lab.</td>
</tr>
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<td></td>
<td>Contrast analyses –</td>
</tr>
<tr>
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<td></td>
<td>Negative effect of completing SSB related Implementation Intentions as compared with control condition (completing homework related Implementation Intentions) on total number of calories consumed, number of calories consumed from beverages, and total amount of sugar consumed.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Negative effect of completing sugar sweetened beverage (SSB) related Implementation Intentions AND participating in SSB related Go/No-Go Task as compared with control</td>
</tr>
</tbody>
</table>
Implementation Intentions AND homework related Go/No-Go Task) on choosing unhealthy drinks and grams of sugar consumed.

No effect of completing SSB related Go/No-Go Task on number of calories consumed, number of calories consumed from beverages, grams of sugar consumed, or grams of sugar from drinks consumed.

All contrast analyses accounted for baseline inhibition and SSB consumption.

Supplementary Analyses – No moderation or main effect of working memory on any of the analyses.

Chung, YC, Park, CH, Kwon, HK, Park, YM, Young, SK, Doo, JK, Shin, DH, Jung, ES, Oh, MR, & Soo, WC (2011) Korea

Mean BMI = 21.09, SD = 1.98 (Mixed-Grain Group)

Mean BMI = 22.20, SD

Computerized Neuro-psychological Test (CNT) – Stroop Task

Meals provided to participants and compliance checks conducted

Intervention-Longitudinal

No relation between diet type and (mixed grain or control group) performance on Stroop Task after 9 weeks

Did not adjust for BMI, but no significant differences between mixed-grain group and normal diet group at baseline.
### Working Memory

**Preschool (Ages 3-6)**

Malaysia – All Weight Status  
Mean $zBMI = -0.48, SD = 0.83$; Excluded children not within $2 SD$ of expected $zBMI$ for age  
M=67 months (Kindergarten year)  
Cognitive Drug Research Battery (CDR) – Computerized Spatial Working Memory Task and Numeric Working Memory Task  
Lab-Based Food Task  
Intervention-Cross-sectional  
Positive relation between consumption of glucose fortified drink and spatial working memory.  
Positive relation between isomaltulose drink and numeric working memory. Better numeric working memory in children who received isomaltulose drink as compared with reformulated lactose drink or glucose drink.  
Did not adjust for $zBMI$.

**Elementary (Ages 7-10)**

Sheppard, KW, & Cheatham, C (2013)  
U.S.  
Not reported  
M=8.38 years (7-9 years)  
Cambridge Neuro-psychological Test Assessment Battery (CANTAB) - Spatial Span Task (computerized)  
24-Hour Dietary Recall (completed by child with assistance from parent)  
Cross-sectional  
No relation between consumption of fatty acids and Spatial Span Task performance  
Trending positive relation ($p=.07$) between n:6:n:3 fatty acid ratio and
<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Ethnicity</th>
<th>Sample Size</th>
<th>Age</th>
<th>Task</th>
<th>Recall Method</th>
<th>Analysis</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheppard, KW &amp; Cheatham, CL (2017)</td>
<td>U.S., Majority Caucasian</td>
<td>Not reported</td>
<td>M=8.1 years (7-9 years)</td>
<td>41</td>
<td>CANTAB – Computerized Spatial Working Memory Task</td>
<td>24-Hour Dietary Recall (completed by child with assistance from parent)</td>
<td>Cross-sectional</td>
<td>No relation between other consumption variables (e.g., total kcal consumed, mean n-3 or n-6 fatty acid intake) and Spatial Working Memory Task performance. Did not adjust for BMI.</td>
</tr>
<tr>
<td>Kirby, A, Woodward, A, Jackson, S, Yang, W, &amp; Crawford, MA (2010)</td>
<td>U.K.</td>
<td>Mean BMI %ile = 69.57, SD = 27.65 (Supplementation Group)</td>
<td>M=9.1 years (8-9 years)</td>
<td>235</td>
<td>Working Memory Test Battery for Children</td>
<td>Supplements given to children then cheek cell analysis of fatty acid conducted to verify consumption</td>
<td>Intervention - Longitudinal</td>
<td>No relation between supplementation of omega-3 fatty acids and performance on the Working Memory Test Battery for Children after 24 weeks. Did not adjust for BMI.</td>
</tr>
<tr>
<td>Study</td>
<td>Location</td>
<td>Ethnicity</td>
<td>Sample Mean BMI</td>
<td>Sample Mean Age</td>
<td>Task/Procedure</td>
<td>Design</td>
<td>Results</td>
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</tr>
<tr>
<td>Early Adolescence (Ages 10-13)</td>
<td></td>
<td></td>
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<tr>
<td>Stautz, K, Pechey, R, Couturier, DL, Deary, JI, &amp; Marteau, M (2016)</td>
<td>U.K., Majority Caucasian</td>
<td>Mean BMI = 20.38, SD = 3.52, M = 10 years (10-13 years)</td>
<td>6069 Counting Span Task Food Diary (completed by child with assistance from parent)</td>
<td>Longitudinal</td>
<td>Positive correlation between Counting Span Task performance and fruit and vegetable consumption No such correlation when adjusting for intelligence Did not adjust for BMI, but instead looked at BMI as an outcome variable in separate analysis</td>
<td></td>
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</tr>
<tr>
<td>Sheppard, KW &amp; Cheatham, CL (2017)</td>
<td>U.S., Majority Caucasian</td>
<td>Did not report M = 10.97 years (10-12 years)</td>
<td>37 CANTAB – Computerized Spatial Working Memory Task 24-Hour Dietary Recall (completed by child with assistance from parent)</td>
<td>Cross-sectional</td>
<td>Positive association between omega-3 fatty acids and performance on Spatial Working Memory Task No relation between omega-6 to omega-3 fatty acid ratio and performance on Spatial Working Memory Task Did not adjust for BMI</td>
<td></td>
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</tr>
<tr>
<td>Brindal, E, Baird, D, Slater, A, Danthiir, V, Wilson, C, Bowen, J, &amp; Noakes, M (2013)</td>
<td>Australia</td>
<td>Mean BMI = 19.2 (SD = 0.44), M = 11.6 years (10-12 years)</td>
<td>40 Digit Span Task Lab-Based Food Task</td>
<td>Intervention-Cross-sectional</td>
<td>No relation between glycemic load of a test drink and Digit Span Task performance, adjusted for zBMI (but only BMI is reported in manuscript).</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Study</td>
<td>Country</td>
<td>Sample Size</td>
<td>Age Range</td>
<td>Test/measures</td>
<td>Design/Relation</td>
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<tr>
<td>Kennedy, DO, Jackson, PA, Elliott, JM, Scholey, AB, Robertson, BC, Greer, J, Tiplady, B, Buchanan, T, &amp; Haskell, CF (2009)</td>
<td>U.K.</td>
<td>M=11 years</td>
<td>90</td>
<td>CDR Battery – Computerized Numeric Working Memory Task; Diary card to conduct compliance with intervention</td>
<td>Intervention - Longitudinal No relation between any level of DHA supplementation (i.e., an omega-3 fatty acid) and performance on Numeric Working Memory Task after 56 days of supplementation. Did not adjust for BMI, but intervention and placebo groups did not differ from each other at baseline</td>
<td></td>
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</tr>
<tr>
<td>Zhang, J, Hebert, J, &amp; Muldoon, M (2005)</td>
<td>U.S.</td>
<td>3666</td>
<td>6-16 years</td>
<td>Digit Span subtests - Wechsler Intelligence Scale for Children Revised (WISC-R); 24-Hour Dietary Recall (Parent-report of child dietary intake)</td>
<td>Cross-sectional Positive relation between Digit Span performance and polyunsaturated fat consumption, adjusting for BMI Negative relation between Digit Span performance and cholesterol consumption, adjusting for BMI No relation between Digit Span performance and other dietary variables (e.g., total fat, saturated fat</td>
<td></td>
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</tbody>
</table>
**Late Adolescence (Ages 14-17)**

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Sample Details</th>
<th>Age</th>
<th>Sample Size</th>
<th>Outcome Measures</th>
<th>Dietary Intake/Intervention</th>
<th>Dietary Intake/Intervention Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nyaradi, A, Foster, JK, Hickling, S, Li J, Ambrosini, GL, Jacques, A, &amp; Oddy, WH (2014)</td>
<td>Australia</td>
<td>Not reported</td>
<td>M=14 years (N.A.)</td>
<td>589</td>
<td>Groton Maze Learning Task (Immediate and Delayed Recall)</td>
<td>Food Frequency Questionnaire</td>
<td>No relation between “healthy” diet (e.g., high in fruits, vegetables, whole grains, legumes, fish, versus “Western”) at age 14 and errors in performance on Groton Maze Learning Task at age 17</td>
</tr>
<tr>
<td>Chung, YC, Park, CH, Kwon, HK, Park, YM, Young, SK, Doo, JK, Shin, DH, Jung, ES, Oh, MR, &amp; Soo WC (2011)</td>
<td>Korea</td>
<td>Mean BMI = 21.09, SD = 1.98 (Mixed-Grain Group)</td>
<td>M=16.2 years (Tenth, Eleventh Grade Years)</td>
<td>28</td>
<td>Computerized Neuro-psychological Test (CNT) – Digit Span Task</td>
<td>Meals provided to participants and compliance checks conducted</td>
<td>No relation between diet type and (mixed grain or control group) performance on Digit Span Task after 9 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean BMI = 22.20, SD = 3.34 (Normal Diet Group)</td>
<td></td>
<td></td>
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<td></td>
<td>Did not adjust for BMI, but no significant differences between mixed-grain group and normal diet group at baseline</td>
</tr>
</tbody>
</table>
### Cognitive Flexibility

#### Elementary (Ages 7-10)

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Sample Details</th>
<th>Measures</th>
<th>Study Design</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pieper, JR, &amp; Laugero, KD (2013)</td>
<td>U.S.</td>
<td>Mean BMI %ile = 63.0 (8.5-98.4) M=4.4 years (3-6 years)</td>
<td>Computerized Dots Task</td>
<td>Cross-sectional</td>
<td>No relation between calories consumed in the absence of hunger (from sweet or savory foods) and performance on the Dots Task. Did not adjust for BMI.</td>
</tr>
<tr>
<td>Khan, NA, Raine, LB, Drollette, ES, Scudder, MR, &amp; Hillman, CH (2015)</td>
<td>U.S.</td>
<td>Mean BMI %ile = 65.4, SD = 28.3 M = 8.8 years (7-10 years)</td>
<td>Color-Shape Task switching paradigm</td>
<td>Cross-sectional</td>
<td>Negative relation between Color-Shape Task performance and cholesterol, saturated fat consumption, adjusting for BMI. No report on relation between Color-Shape Task performance and other dietary intake (e.g. carbohydrates, protein).</td>
</tr>
<tr>
<td>Brindal, E, Baird, D, Slater, A, Danthiir, V, Wilson, C, Bowen, J, &amp; Noakes, M (2013)</td>
<td>Australia</td>
<td>Mean BMI = 19.2 (SD= 0.44) M=11.6 (10-12 years)</td>
<td>Attention Switching Task (see Rogers &amp; Monsell, 1995)</td>
<td>Lab-Based Food Task</td>
<td>Intervention-Cross-sectional</td>
</tr>
</tbody>
</table>
### Overall EF

**Elementary (Ages 7-10)**

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Ethnicity</th>
<th>Sample Size</th>
<th>Age</th>
<th>Measure</th>
<th>Questionnaire</th>
<th>Data Collection</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riggs, NR, Spruijt-Metz, D, Sakuma, K, Chou, C, &amp; Pentz, MA (2010)</td>
<td>U.S.</td>
<td>Majority Hispanic</td>
<td>Not reported</td>
<td>$M = 9.4$ years (Fourth grade year)</td>
<td>107</td>
<td>Behavior Rating Inventory of Executive Function (BRIEF-SR; child report)</td>
<td>Food Frequency Questionnaire (completed by child)</td>
<td>Cross-sectional</td>
</tr>
<tr>
<td>Riggs N, Chou CP, Spruijt-Metz D, Pentz MA (2010)</td>
<td>U.S.</td>
<td>Majority Hispanic or African-American</td>
<td>Not reported</td>
<td>$M = 9.4$ years (Fourth grade year)</td>
<td>184</td>
<td>Behavior Rating Inventory of Executive Function (BRIEF-SR; child report)</td>
<td>Food Frequency Questionnaire (completed by child)</td>
<td>Longitudinal</td>
</tr>
</tbody>
</table>

Positive relation between BRIEF-SR scores and fruit/vegetable consumption (cross-sectional) 

No relation between BRIEF-SR scores and snack food consumption (longitudinal) 

Positive relation between BRIEF-SR scores and fruit/vegetable consumption (longitudinal) 

Did not adjust for BMI
Riggs, NR, Spruijt-Metz, D, Chou, C, & Pentz, MA (2012)  
U.S., Approx. 75% non-Caucasian  
Not reported  
$M = 9.3$ years (Fourth grade year)  
1587  
Behavior Rating Inventory of Executive Function (BRIEF-SR; child report)  
Food Frequency Questionnaire (completed by child)  
Cross-sectional  
Negative relation between BRIEF-SR scores and snack food consumption  
Did not adjust for BMI  
Positive relation between BRIEF-SR scores and fruit/vegetable consumption

U.S., Approx. 75% non-Caucasian  
Not reported  
$M = 9.3$ years (Fourth grade year)  
1005  
Behavior Rating Inventory of Executive Function (BRIEF-SR; child report)  
Food Frequency Questionnaire (completed by child)  
Longitudinal  
Negative relation between BRIEF-SR scores and “high-calorie low nutrient” snack food consumption (cross-sectional)  
No relation between BRIEF-SR scores and “high-calorie low nutrient” snack food consumption (longitudinal)  
Did not adjust for BMI
Inhibition

Fifteen studies included in this review examined associations between inhibition and dietary intake. Fourteen used at least one direct (usually computerized) measure of inhibition: the most popular being a stop-signal task, in which participants must either respond or inhibit response to presented stimuli, or a flanker task, which is similar to a stop-signal task (Ames et al., 2014, 2016; Chung et al., 2012; Folkvord, Veling, & Hoeken, 2016; Guerrieri, Nederkoom, & Jansen, 2007; Kennedy et al., 2009; Khan, Raine, Drollette, Scudder, Kramer et al., 2015; Levitan et al., 2015; Nederkoorn, Dassen, Franken, Resch, & Houben, 2015; Pentz, Spruijt, Chou, & Riggs, 2011; Pieper & Laugero, 2013; Sheppard & Cheatham, 2017; Stautz, Pechey, Couturier, Deary, & Marteau, 2016; Whyte, Schafer, & Williams, 2016). Two studies also used a parent-report questionnaire to assess inhibition in addition to other tasks (Pieper & Laugero, 2013; Stautz et al., 2016), one study also child-report questionnaires to measure inhibition and dietary intake (Ames et al., 2016), and one study used a child-report questionnaire as its only measure of inhibition (Pentz et al., 2011). Regarding measurement of dietary intake, five studies used 24-hour dietary recalls (Sheppard & Cheatham, 2017), food frequency questionnaires (Ames et al., 2014; Pentz et al., 2011) or food diaries (Khan, Raine, Drollette, Scudder, Kramer, et al., 2015; Stautz et al., 2016), and four studies used lab-based food paradigms (e.g., presenting children with food in the lab) (Guerrieri et al., 2007; Levitan et al., 2015; Nederkoorn et al., 2015; Pieper & Laugero, 2013). Finally, four studies used interventions to improve dietary intake and then measured subsequent inhibition skills (Chung et al., 2012; Kennedy et al., 2009; Schröder et al., 2016; Whyte et al., 2016), and two studies used an intervention to train inhibition and then measured subsequent dietary intake (Ames et al., 2016; Folkvord et al., 2016).
**Preschool (Ages 3-6).** Two cross-sectional studies included in this review examined associations between inhibition and dietary intake in preschool (Levitan et al., 2015; Pieper & Laugero, 2013), a period of rapid development of inhibition skills. Using a stop-signal task, Levitan and colleagues (2015) assessed the relation between inhibition and dietary intake in a lab-based snack task in four-year old children. To more accurately simulate a family meal, mothers and children were both included in the task and had identical sets of snacks to consume, including cereal, fruit, cheese, and nuts. Results revealed that, accounting for maternal snack intake, children with poorer inhibition consumed significantly more foods high in sugar and carbohydrates than those who had better inhibition. Although the authors did not control for BMI, per se, they did consider maternal BMI and child birth weight as potential covariates and found that these variables were not related to snack food consumption. There was no relation between total caloric intake, protein intake, or fat intake and inhibition. In another study that utilized a lab-based task, Pieper and Laugero (2013) examined dietary intake in the absence of hunger in children ages 3-6. They presented children with both sweet (frosted cookies) and savory snacks (pretzels and cheese crackers) and found that consumption of those snacks in the absence of hunger was not significantly related to performance on a flanker task, nor was it related to parent report of inhibition problems. The authors did not consider BMI in the analysis of inhibition and dietary intake. Finally, in the preschool age range, there were no longitudinal studies of the relation between inhibition and dietary intake in preschool children, and there were no intervention studies aimed at targeting either inhibition or dietary intake.

**Elementary (Ages 7-10).** Seven identified studies examined relations between inhibition and dietary intake in the 7-10-year-old age range and all included studies were cross-sectional. Of those, three studies observed associations between inhibition and some form of unhealthy
dietary intake (Guerrieri et al., 2007; Nederkoorn et al., 2015; Pentz et al., 2011), two studies observed some aspect of healthy dietary intake (Khan, Raine, Drollette, Scudder, Kramer, et al., 2015; Sheppard & Cheatham, 2017), one study described the effects of a dietary intake intervention (Whyte et al., 2016), and one study described the effects of an intervention meant to improve inhibition (Folkvord et al., 2016).

Of the three studies that measured some aspect of unhealthy dietary intake in children ages 7-10, two found a significant association with inhibition. Nederkoorn et al. (2015) found that poor performance on a stop-signal task was cross-sectionally associated with eating more high calorie foods in the lab (i.e., candy and chips), but not with eating lower calorie foods (i.e., grapes and carrots), even in the absence of hunger, in children ages 7-9. Using a cross-sectional design, Pentz et al. (2011) found that more problems on the self-report Behavior Rating Inventory of Executive Function (BRIEF-SR) Inhibit scale (Guy, Isquith, & Gioia, 2004) were associated with greater intake of high calorie foods (i.e., soft drinks, fried snacks, candy) in fourth grade children as measured by a food frequency questionnaire completed by the child. In contrast, a third cross-sectional study found that poor performance on a stop-signal task was not related to increased consumption of marshmallow candy in the lab in children ages 8-10 (Guerrieri et al., 2007). Although Nederkoorn et al. (2015) and Guerrieri et al. (2007) measured BMI to address related research questions (see Table 1), none of the included studies accounted for BMI in analyses examining the relation between inhibition and dietary intake.

With regards to the relation between inhibition and healthy dietary intake, the results were variable. Khan and colleagues (2015) found that better inhibition was related to higher dietary fiber consumption and overall better dietary quality in children ages 7-9, controlling for percent body fat mass. Inhibition was measured using a computerized task similar to a stop-
signal task, and dietary intake was measured using three-day dietary recalls completed by children (with parental assistance) then Healthy Eating Index scores were derived to measure dietary quality (Khan, Raine, Drollette, Scudder, Kramer, et al., 2015). In contrast to these findings, also using 24-hour dietary recalls, Sheppard and Cheatham (2017) found that greater consumption of omega-3 fatty acids (found in foods such as fatty fish, eggs, and flaxseed oil) was not related to inhibition in children ages 7-9, as measured by the Cambridge Neuropsychological Test Automated Battery (CANTAB), a computerized measure that assesses EF. Additionally, the study also examined the ratio of omega-6 fatty acids (found in foods such as meat, corn, nuts and seeds) to omega-3 fatty acids. Past research has shown that eating higher levels of omega-6 fatty acids fatty acids as compared with omega-3 fatty acids, may be harmful (Kirby, Woodward, Jackson, Wang, & Crawford, 2010); however, Sheppard and Cheatham (2017) found that the ratio of omega-3 to omega-6 was also not related to inhibition. The study was cross-sectional and did not measure or account for BMI in the analyses. Overall, there were no longitudinal studies examining the relation between inhibition and dietary intake in elementary age youth.

In addition to studies that examined the cross-sectional relation between inhibition and dietary intake in elementary age youth, two studies described interventions in this age range. One study examined the impact of an intervention meant to increase blueberry consumption in children ages 7-10 (Whyte et al., 2016). After breakfast, children received either a drink containing 15 or 30 mg of freeze-dried wild blueberry powder or a control drink that was blueberry flavored but contained no actual powder. Next, inhibition was measured using both a go/no-go task and a flanker task. Results indicated a linear relation between amount of blueberry powder consumed and performance on the flanker task, such that consumption of 30 mg of
powder resulted in the best performance and consumption of the control drink resulted in the worst performance. There was no significant impact of blueberry powder consumption on performance on the go/no-go task. The study did not account for BMI.

In addition to a dietary intake intervention, one study examined an intervention aimed at training EF in this age range. In the study, Folkvord et al. (2016) attempted to train inhibition skills using a food-based go/no-go task with children ages 7-10. In the task, unhealthy food images were associated with no-go trials (i.e., children had to inhibit their response to the task when unhealthy foods appeared) and non-food images were associated with go trials (i.e., children were instructed to make a response when non-food images appeared). They found that children who were trained using the food-based go/no-go task ate less candy in the lab than those who were not trained using the task, accounting for BMI.

**Early adolescence (Ages 10-13).** Two identified studies assessed inhibition in children ages 10-13. One study presented a longitudinal examination of the relation between inhibition and dietary intake, over the course of three years (Stautz et al., 2016), and the other presented an intervention to alter dietary intake and examined subsequent inhibition (Kennedy et al., 2009).

Stautz and colleagues (2016) measured inhibition and healthy dietary intake (i.e., fruit and vegetable consumption) longitudinally, and found no significant association between performance on a stop-signal task at age 10 and consumption of fruits and vegetables at age 13. Inhibition was measured using a stop-signal task and dietary intake was measured using a three-day food diary completed by the child with the help of the parent (Stautz et al., 2016). The authors did not include BMI or weight status in the analyses of EF and dietary intake. Instead, they conducted separate analyses to assess whether EF predicted weight status independent of
analyses used to assess fruit and vegetable consumption. This represented the only study that measured the relation between inhibition and dietary intake longitudinally, in any age group.

One study examined the impact of a dietary intake intervention on inhibition. Kennedy et al. (2009) assessed the impact of an eight-week supplementation of DHA, a healthy omega-3 fatty acid, on inhibition in healthy 10-12-year-old children, using a flanker task. They found that DHA supplementation was not associated with improvements in inhibition eight weeks later. Although Kennedy et al. determined that there were no differences in BMI between intervention and placebo groups, the study did not consider BMI as a covariate in the analyses. No identified studies examined the impact of interventions targeting inhibition on subsequent dietary intake in children ages 10-13.

Late adolescence (Ages 14-17). Three studies in the current review examined inhibition and dietary intake in late adolescence (Ames et al., 2014, 2016; Chung et al., 2012), a period of continued development of inhibition skills. A cross-sectional study investigated the association between inhibition and dietary intake (Ames et al., 2014), and another study presented an intervention aimed at improving dietary intake and then assessed subsequent inhibition skills (Chung et al., 2012), and a different study presented an intervention aimed at improving EF and then assessed subsequent dietary intake skills (Ames et al., 2016).

Using a cross-sectional design, Ames and colleagues (2014) used both a food- and a non-food specific stop-signal task to examine inhibition in youth ages 14-17. Close to 40% of participants in the study were overweight or had obesity. Using structural equation modeling, they found that poorer performance on both versions of the stop-signal task were significantly associated with both sweet snack consumption and salty/fatty snack consumption in males accounting for BMI (Ames et al., 2014). Snack consumption was measured by a food frequency
questionnaire. In females, this association was not significant; however, the study found that females who performed worse on the stop-signal tasks were significantly more likely to endorse binge eating behavior. Although the neural and psychological correlates of binge eating disorder are beyond the scope of this review (see Kober & Boswell, 2018 for a review), these findings lend support to the idea that inhibition impairments in late adolescence are associated with obesogenic behaviors for both male and female youth.

Two studies also presented interventions to impact either dietary intake or inhibition. In the first study, Chung and colleagues (2012) investigated the impact of a randomized controlled trial of a nine-week dietary intervention to increase mixed-grain consumption (i.e., brown rice, black rice, kidney beans, and walnuts) in youth ages 15-17. Using a Stroop task to measure inhibition, the study found no impact of the intervention on inhibition skills. They also found that there were no differences in BMI between the intervention group and the control group but did not consider BMI as a covariate in the overall analyses. This represented the only longitudinal study of inhibition and dietary intake in late adolescents. In the second study, Ames and colleagues (2016) aimed to “train” inhibition using both a sugar-sweetened beverage (SSB) go/no-go task in which “go” trials represented no-calorie drinks, like water, and “no-go” trials represented SSBs, and an intervention meant to help participants change their intentions toward SSBs. In the intention intervention, participants completed a computerized task where they had to complete sentences like the following, “If I see Sprite, then I will resist it.” Students completed either the SSB go/no-go and the SSB intention intervention or they completed only one of the SSB interventions along with a control intervention. Prior to participating in the intervention, participants were given a short survey to assess for problems with inhibition, and only youth who identified having problems with inhibition were included in the study.
Participants were also given a generic go/no-go task and a food frequency questionnaire to assess inhibition and SSB intake, respectively, prior to the intervention. After completing inhibition training in the lab, participants were given the opportunity to consume a variety of beverages. Results indicated no overall effects of the intervention on SSB intake in the lab. However, contrast analyses meant to compare each component of the condition to one another indicated that participants who participated in the SSB implementation intervention consumed fewer calories and less total sugar than those who did not. They also found that those who participated in both the SSB implementation intervention and the SSB go/no-go task chose fewer unhealthy drinks and consumed fewer grams of sugar than those who did not. Ames and colleagues (2016) also assessed whether baseline levels of working memory might have impacted the intervention but found no significant effects. Although the contrast analyses accounted for baseline levels of inhibition and SSB consumption, they did not account for BMI.

In sum, the research examining the association between inhibition and either healthy or unhealthy dietary intake is equivocal, and there is very little research on the relation between inhibition and dietary intake over time, therefore it is difficult to determine directionality. In preschool children, the current literature is too small to make firm conclusions, but there is some evidence that poor inhibition may be associated with unhealthy dietary intake in the elementary years. However, the findings suggest that this relation becomes more complicated as children age, when other factors such as gender may begin to play a larger role. Although most studies did not account for BMI, those that did found that the relation between poor inhibition and unhealthy dietary intake was still significant. With regard to the inhibition and healthy dietary intake, the current literature demonstrates little evidence for an association. Finally, in terms of interventions aimed at altering behavior, there is little evidence to suggest that a short-term
change in dietary intake is associated with improvements in inhibition. However, with regard to the inverse relation, a small body of literature indicates that “training” EF as a way to decrease unhealthy dietary intake may be helpful.

**Working Memory**

Ten studies assessed the association between working memory and dietary intake (Brindal et al., 2013; Chung et al., 2012; Kennedy et al., 2009; Kirby et al., 2010; Mohd Taib, Mohd Shariff, Wesnes, Abu Saad, & Sariman, 2012; Nyaradi et al., 2014; Sheppard & Cheatham, 2013, 2017; Stautz et al., 2016; Zhang, Hebert, & Muldoon, 2005). Seven studies used a computerized neuropsychological test battery (CANTAB, CogState, etc.) to assess either visuospatial working memory, phonological working memory, or both (Chung et al., 2012; Kennedy et al., 2009; Mohd Taib et al., 2012; Nyaradi et al., 2014; Sheppard & Cheatham, 2013, 2017; Stautz et al., 2016). The other three studies used experimenters to administer phonological working memory tasks such as the digit span task, where children are asked to recall numbers that are read aloud either forward, backward, or both (Brindal et al., 2013; Kirby et al., 2010; Zhang et al., 2005). Dietary intake was measured by either 24-hour dietary recall administered to either the parent or the child and parent together (Sheppard & Cheatham, 2013, 2017; Zhang et al., 2005), food frequency questionnaires (Nyaradi et al., 2014), or a food diary (Stautz et al., 2016). Finally, five studies examined interventions aimed at improving dietary intake and then measuring subsequent working memory (Brindal et al., 2013; Chung et al., 2012; Kennedy et al., 2009; Kirby et al., 2010; Mohd Taib et al., 2012).

**Preschool (Ages 3-6).** There were no identified studies focused on understanding associations between working memory and dietary intake in preschoolers outside of a dietary intervention. In the one intervention study, Mohd Taib et al. (2012) investigated the impact of
drinks fortified with glucose, isomaltulose (a carbohydrate that breaks down into glucose at a reduced rate and is naturally found in honey and sugar cane), and lactose on working memory in children (age 5) in order to test the theory that consumption of different types of dietary carbohydrates yields different cognitive response. Spatial working memory was assessed through a computerized version of the digit span task in which numbers are presented on the screen and children have to choose which numbers they saw, and visual working memory was assessed through a visual task where computers had to remember and identify locations of blocks presented on the screen using three computerized neuropsychological test batteries administered 60, 120, and 180 minutes after consumption of the drink. Mohd Taib and colleagues found that all children, except those who received the glucose fortified drink, exhibited a decline in spatial working memory accuracy as the morning progressed. For numeric working memory, all children exhibited a decline in accuracy as the morning progressed, but children who received the isomaltulose drink showed less decline than those who received the reformulated lactose drink or the glucose drink. The study did not account for BMI in the main analyses but excluded children who were not within two standard deviations of expected BMI for age. There were no intervention studies aimed at training working memory to alter dietary intake in this age range.

**Elementary (Ages 7-10).** Three studies examined associations between healthy dietary intake, specifically omega-3 and omega-6 fatty acid intake, and working memory in children ages 7-10 (Kirby et al., 2010; Sheppard & Cheatham, 2013, 2017). In contrast to their findings about inhibition, Sheppard and Cheatham (2013) found that a higher ratio of omega-6 (found in foods such as meat, corn, nuts and seeds) to omega-3 (found in foods such as fatty fish, eggs, and flaxseed oil) fatty acids in children ages 7-9, as measured by child and parent 24-hour dietary recall, was associated with more impairments in visuospatial working memory, as measured by a
computerized neuropsychological test battery. However, when Sheppard and Cheatham (2017) attempted to replicate this finding with a different sample of children, they found that there was no significant relation between the omega-6 to omega-3 ratio and visuospatial working memory in this age group. Additionally, although higher levels of omega-3 fatty acids have been found to promote brain development (Innis, 2008), both studies found higher levels of omega-3, considered separately from levels of omega-6, were not significantly associated with working memory performance in elementary age children (Sheppard & Cheatham, 2013, 2017). Neither of the studies measured or accounted for BMI.

With regards to interventions, one study examined the impact of increasing omega-3 fatty acids on subsequent working memory. In the study, Kirby and colleagues (2010) found that a 24-week intervention to increase omega-3 fatty acids in children ages 8-10 did not significantly impact working memory, as measured by a digit span task. There was no difference in mean BMI percentile of the children in the study receiving the intervention and the placebo, but main analyses did not account for BMI as a covariate. There were no intervention studies in this age range that measured the impact of a working memory intervention on subsequent dietary intake. Additionally, outside of one intervention study, there were no other longitudinal studies that observed the relation between working memory and dietary intake in this age range. There were also no studies that examined working memory interventions to alter dietary intake in this age range.

**Early adolescence (10-13).** Four studies measured working memory in early adolescents. Working memory was measured using computerized neuropsychological test batteries in all studies except Brindal et al. (2013), who used a traditional digit span task. Two studies investigated associations between working memory and some form of healthy dietary intake
(Sheppard & Cheatham, 2017; Stautz et al., 2016), and two studies presented dietary intake interventions aimed at making dietary intake healthier (Brindal et al., 2013; Kennedy et al., 2009). Extending their findings from elementary age children, Sheppard and Cheatham (2017) also investigated the impact of omega-6 and omega-3 fatty acids in children ages 10-12. They found that in this age range, higher levels of omega-3 fatty acids were associated with better working memory performance, but the ratio of omega-6 to omega-3 fatty acids was not significantly associated with working memory, standing in contrast to their findings from elementary age children. Again, Sheppard and Cheatham measured working memory using a computerized neuropsychological test battery and measured dietary intake using child and parent 24-hour dietary recall. In addition to this, a second study of early adolescent youth measured the longitudinal impact of visual working memory, using a task where participants were asked to count several sets of dots on a screen and remember the number of dots contained in each set, on healthy dietary intake, as measured by a food diary (Stautz et al., 2016). In the study, Stautz et al. found a significant positive association between visual working memory at age 10 and fruit and vegetable consumption at age 13. However, when the authors included overall IQ score as a covariate in the analyses, this association was no longer significant. The study did not account for BMI.

Two of the included studies described dietary interventions. Kennedy et al. (2009) administered an eight-week intervention to increase omega-3 fatty acid consumption in 10-12-year-olds. They assessed numeric working memory, using a computerized test battery, at the beginning and at the end of the intervention and found no significant improvements in working memory after the intervention. The study did not account for BMI. Brindal et al. (2013) investigated the impact of consumption of a beverage with either high or low glycemic load (i.e.,
a milk drink with or without added glucose) on working memory in 10-12-year-olds. Working memory was measured using a digit span task at baseline and then at 60, 120, and 180 minutes after the drink was consumed. The study found that glycemic load had no significant impact on working memory, accounting for BMI. There were no interventions aimed at improving working memory to alter dietary intake in this age range.

**Elementary/Adolescence (Ages 6-16).** One study measured working memory in children across the elementary and adolescent age range. Zhang and colleagues (2005), measured both healthy and unhealthy dietary intake in a cross-sectional study of children ages 6-16. Using a digit span task where participants were asked to remember a set of numbers in order, they found that, accounting for BMI, better phonological working memory was associated with healthier dietary intake (i.e., higher amount of polyunsaturated fats), while poorer phonological working memory was associated with unhealthy dietary intake (i.e., higher amount of carbohydrates, saturated fat, and cholesterol). Dietary intake was measured using a 24-hour dietary recall administered to the child’s mother (Zhang et al., 2005). No other studies in this review combined elementary and adolescent youth.

**Late adolescence (14-17).** Two studies measured the association between working memory and dietary intake in late adolescents. One study represented a longitudinal observation of the impact of dietary intake on working memory, and the other described an intervention to improve dietary intake and then measured subsequent working memory. In the longitudinal study, Nyaradi and colleagues (2014) found that higher adherence to a “Western” diet (represented by high intake of fast food, red and processed meat, sugar sweetened beverages and fried food) was associated with more errors on a maze learning task of working memory at age 17, while higher intake of fruit at 14 were associated with fewer errors at age 17. Dietary intake
was measured in the study using food frequency questionnaires. The study did not account for BMI. In the intervention study, Chung and colleagues (2012) found that a 9-week intervention aimed at increasing dietary consumption of mixed-grain in youth ages 15-17 had no significant impact on working memory, as measured by a digit span task. Chung et al. excluded youth who were not within 30% of expected body weight, but did not account for BMI in the analyses. There were no identified studies that aimed to train working memory to alter dietary intake in this age range.

Overall, the literature on the association between working memory and dietary intake is variable. Few studies examined working memory in preschool and elementary age children, therefore it is difficult to make conclusions about these age groups. However, one cross-sectional study examined working memory in children ranging in age from elementary school to adolescence, and found that better working memory was associated with healthier dietary intake (Zhang et al., 2005). Because of the wide age range, the impact of the developmental processes that occur during early childhood versus during adolescence are unclear. From a developmental perspective, there is evidence to suggest that working memory capacity is developed in the first years of life, before a child enters school (Garon et al., 2008). Therefore, it is possible that, in the domain of working memory, combining ages 6-16 may be developmentally appropriate. However, other aspects of development that occur between ages 6-16, such as more responsibility for dietary intake and less parental control, complicate the findings. Outside of the Zhang et al. (2005) study, there is evidence of a positive cross-sectional association between some form of healthier dietary intake (e.g., omega-3 fatty acids, fruit and vegetables) and better working memory in both early and late adolescence. There is also some support for a bi-directional longitudinal association between working memory and dietary intake in adolescents.
That is, healthy dietary intake may predict better working memory and unhealthy dietary intake may predict more impairment in working memory. Additionally, better working memory may also predict healthier dietary intake. With regards to intervention studies, there is very little evidence of the effectiveness of short-term interventions to alter dietary intake on subsequent working memory performance in children over the age of five. There were no studies that investigated the impact of working memory training interventions on dietary intake. Finally, across both observational and intervention studies, it is difficult to ascertain the role of BMI in the relation between working memory and dietary intake, as most studies did not account for it.

**Cognitive Flexibility/Task Switching**

Three identified studies assessed cognitive flexibility/task switching in the context of healthy or unhealthy dietary intake (Brindal et al., 2013; Khan, Raine, Drollette, Scudder, & Hillman, 2015; Pieper & Laugero, 2013). Two studies used computerized neuropsychological test batteries to assess cognitive flexibility (Khan, Raine, Drollette, Scudder, & Hillman, 2015; Pieper & Laugero, 2013), and one study used a traditional digit span task (Brindal et al., 2013). Dietary intake was assessed using a 24-hr dietary recall (Khan, Raine, Drollette, Scudder, & Hillman, 2015) and a lab based food task (Pieper & Laugero, 2013). There was also one study that described a dietary intake intervention (Brindal et al., 2013). All five studies were cross-sectional.

**Preschool (Ages 3-6).** Only one study measured cognitive flexibility in preschool children. Pieper and Laugero (2013) assessed the cross-sectional association between cognitive flexibility and eating in the absence of hunger in children ages 3-6. They measured cognitive flexibility using a computerized task in which children had to switch between sets of instructions to identify dots presented on a screen. The study found no significant relations between cognitive
flexibility and eating either salty (cheese crackers and pretzels) or sweet (frosted cookies) snacks in the absence of hunger and did not account for BMI.

**Elementary (Ages 7-10).** One identified study examined cognitive flexibility and dietary intake in elementary age children. Khan and colleagues (2015) used a color-shape switching paradigm, requiring children ages 7-10 to learn tasks associated with particular shapes and colors and then respond to a certain cue telling them which task to use, to assess cognitive flexibility/task switching. They found that, controlling for BMI percentile, slower reaction time and lower accuracy on the task (i.e., poor cognitive flexibility) were associated with higher saturated fat intake and higher cholesterol intake using a 24-hour dietary recall measure completed by the child with the assistance of a parent.

**Early adolescent (Ages 10-13).** There were no identified studies focused on understanding associations between cognitive flexibility and dietary intake in early adolescence outside of a dietary intervention. One study investigated the impact of a dietary intervention to impact cognitive flexibility. Similar to their results for working memory, Brindal et al (2013) found no relation between consumption of drinks with varying glycemic load and cognitive flexibility in youth ages 10-12, as measured by a paper and pencil measure of cognitive flexibility (Rogers & Monsell, 1995), accounting for zBMI.

In sum, there less research on the association between cognitive flexibility and dietary intake than there is on either inhibition or working memory, and the existing research is equivocal. One of the two cross-sectional studies in this review found no significant relation between cognitive flexibility and dietary intake in preschoolers. In contrast, evidence from the other cross-sectional study indicates that there may be a cross-sectional relation between cognitive flexibility and unhealthy dietary intake in elementary age children, accounting for
BMI. Given that all of the included studies were cross-sectional, few conclusions can be made about the directionality of the relation between cognitive flexibility and dietary intake, should such a relation exist. Additionally, little is known about the association between cognitive flexibility and dietary intake in adolescents outside of one intervention study that found no significant impact of a change in dietary intake on cognitive flexibility. There were no intervention studies that examined the possible dietary impact of interventions aimed at altering cognitive flexibility.

**Overall EF**

Given that EF can be conceptualized as both a unitary construct and as many domain-specific skills, we now turn to studies that have evaluated EF as a unitary construct. Although there is evidence of differences in the development of each domain of EF, generally speaking, EF can be observed in preschool, continues to develop throughout middle childhood, and is not fully developed until the mid-twenties (Anderson, 2002).

**Elementary (Ages 7-10).** Four of the identified studies evaluated associations between overall EF and unhealthy dietary intake in elementary age children (Riggs, Chou, et al., 2010; Riggs et al., 2012; Riggs, Spruijt-Metz, Sakuma, Chou, & Penta, 2010; Tate et al., 2015). All four studies represented either cross-sectional or longitudinal investigations of the association between overall EF and dietary intake, and there were no intervention studies examining overall EF. All four studies used a higher order overall EF score, derived from confirmatory factor analysis, representing multiple domains of problems with EF, including inhibitory control, working memory, and organization of materials, as well as emotional control, as measured by BRIEF-SR. Each of these four studies assessed fourth grade students (approximately nine years old) using food frequency questionnaires as a part of a school-based obesity prevention program.
In an initial pilot study of 107 children, Riggs, Spruijt-Metz, et al. (2010) found that children with fewer overall EF problems consumed fewer snack foods (e.g., examples), but found that overall EF was not related to fruit and vegetable consumption. Riggs, Chou, et al. (2010) then found that fewer problems with overall EF at baseline predicted greater fruit and vegetable consumption four months later, but did not predict snack food consumption, using data from the same pilot study. After demonstrating feasibility from the pilot study, a third cross-sectional study by Riggs and colleagues (2012), using an expanded sample of 1,587 children, found that fewer problems with overall EF were associated with higher fruit and vegetable consumption and lower snack food consumption. Finally, the fourth study (Tate et al., 2015), using the same sample as in Riggs et al. (2012), found that fewer problems with overall EF at age nine was associated with lower consumption of high calorie foods (i.e., soft drinks, fried snacks, candy), but was not associated with high calorie food consumption at age ten. However, the study found an indirect longitudinal association between overall EF problems and high calorie food consumption: problems with EF at age nine were associated with increased perception of parent food fast intake six months later, which was in turn associated with increased high calorie food consumption at age ten. Although all four studies utilized data from the same school-based obesity prevention program, they did not account for BMI or weight status in any of the presented analyses.

To summarize, the extant literature suggests that problems with overall EF may be associated with unhealthy dietary intake during the elementary years. However, there is variable evidence of an association between poor overall EF and unhealthy dietary intake when measured longitudinally. There is no literature examining either the relation between overall EF and healthy dietary intake, or overall EF and dietary intake in children outside of the elementary age
range. Additionally, it is unclear whether the relation between overall EF and dietary intake may be influenced by BMI. Finally, given that there are no intervention studies using problems with overall EF as a measure, it is difficult to ascertain whether a decrease in problems with overall EF may impact dietary intake or an improvement in dietary intake may improve problems with overall EF.

Discussion

Given recent evidence that deficits in EF may be related to childhood obesity, it is important to understand how EF may also be associated with dietary intake, an underlying predictor of obesity. Evidence from the obesity literature suggests that differences in EF may partially explain why some children appear to have more difficulty than others choosing to eat healthier foods. However, there is also evidence supporting the inverse relation - that less nutritious dietary intake may lead to problems with EF. Research on the relation between EF and dietary intake has not been integrated across literatures, and no review to date has examined how EF may be differentially associated with dietary intake in youth across development. Overall, the current review indicates that the findings from the literature are equivocal. Findings from cross-sectional studies indicate that although there may be some relation between EF and dietary intake, factors such as age and gender complicate that relation. Additionally, the lack of research on longitudinal associations between dietary intake and EF makes it difficult to understand directionality. The most evidence exists for a positive association between child-reported problems with overall EF and increased unhealthy dietary intake in elementary age youth. However, these findings have not been replicated in children of other ages. Likewise, there is evidence that working memory may be positively associated with healthier dietary intake (i.e., more fruits and vegetables, less junk food) during adolescence but there has been less
examination of working memory and dietary intake in younger children. Finally, there is a dearth of literature on the relation between cognitive flexibility and dietary intake in children of any age, therefore it is not possible to make firm conclusions.

The current review also sought to incorporate findings from interventions seeking to alter either EF or dietary intake to improve the other in order to investigate the practical implications of research demonstrating a relation between EF and dietary intake. Overall, there is much more research examining the impact of altering dietary intake on subsequent EF than there is examining the impact of “training” EF on subsequent dietary intake in youth. Nevertheless, taken together, the existing literature does not support the effectiveness of dietary interventions meant to impact EF in healthy youth, given that only two studies out of eight found a significant relation between a dietary intervention and subsequent performance on an EF measure. However, with regards to the inverse relation, a small amount of literature indicates that it may be possible to train EF in order to impact dietary intake, at least in the short term.

One possible explanation for the mixed findings seen throughout this review is that EF may interact with other individual characteristics to influence dietary intake. Although many studies included at least some demographic covariates (e.g., age, gender, SES, etc.), most did not report investigating those covariates as moderators. Therefore, it is difficult to investigate the possibility that EF is related to dietary intake, but only for certain youth, thus complicating the findings. For example, research from the obesity literature indicates a relation between overweight and EF (Pearce et al., 2018), but given that many studies did not consider BMI in their analyses, or excluded children who were over or underweight, it is unclear whether weight status may impact the relation between EF and dietary intake. Additionally, it is possible that other psychological factors may also impact the relation between dietary intake and EF. Indeed,
there is evidence from the adult literature to suggest that motivation and temptation may play an important role in determining whether an individual will inhibit the desire to consume unhealthy foods (Milyavskaya & Inzlicht, 2017). Furthermore, stress may also interact with EF to influence dietary intake, especially as it relates to decision making in the moment and preference for energy-dense foods that are high in sugar and fat in both children and adults (Hill, Moss, Sykes-Muskett, Conner, & O’Connor, 2018; Torres & Nowson, 2007). In addition to these characteristics, the role of IQ also arose as a potential confounding variable. Stautz et al. (2016) found that associations between working memory and dietary intake in children ages 10-13 were attenuated when IQ was considered as a covariate. Although there is a solid body of evidence showing that EF and IQ are correlated but distinct constructs, research suggests that of all three components of EF, working memory is most highly correlated with intelligence (Friedman et al., 2006a). It is also important to note that the study assessed intelligence using the WISC-III full scale IQ score, which is partially derived by measuring working memory. Therefore, it is possible that collinearity between working memory and IQ may have played a role in the Stautz et al. (2016) findings. Nevertheless, future research should continue to investigate how IQ and EF are related to determine whether it is appropriate to consider the impact of one when investigating the other.

In addition to demographic and psychological characteristics, methodological considerations may also help to explain the mixed findings in this literature. Although only commonly used EF measures were included in this review, the specific type of measure varied across studies, which might have impacted the findings. Additionally, even more so than the EF measures, the dietary measures used across studies were inconsistent and mostly relied on self-report dietary intake which has inherent limitations on reliability (McPherson, Hoelscher,
Alexander, Scanlon, & Serdula, 2000). It must also be noted that in terms of study design, only four studies observed the relation between EF dietary intake over time (Nyaradi et al., 2014; Riggs, Chou, et al., 2010; Stautz et al., 2016; Tate et al., 2015). Three of the studies examined EF as a predictor of dietary intake. Riggs, Chou, and colleagues (2010) reported a significant relation between overall EF and consumption of fruits and vegetables longitudinally. However, the time between measurement of EF and dietary intake was short (~4 months), therefore it is difficult to determine if the time lapsed was sufficient to interpret the data as truly measuring two distinct time points. Furthermore, neither of the two studies that measured the variables at least one year apart lent strong support to a longitudinal relation between EF and dietary intake. Using data from the same sample as Riggs and colleagues (2010), Tate and colleagues (2015) found no direct relation between overall EF at age 9 and unhealthy dietary intake at age 10, further supporting the hypothesis that the short amount of time between measurement may have driven the previous results. Likewise, in addition to their examination of working memory, Stautz and colleagues (2016) also found no longitudinal relation between inhibition and healthy dietary intake in youth ages 10-13, with or without accounting for intelligence. However, the role of development is important to consider when evaluating these studies. Given that the majority of longitudinal studies investigating EF as a predictor of dietary intake were conducted in children ages 10-13, it is difficult to extend the findings to youth of other ages. It is possible that the developmental changes in EF that naturally occur between preadolescence and adolescence may be far greater than the changes in dietary intake seen during this time. Therefore, EF and dietary intake may have different trajectories across adolescence, which would in turn impact their longitudinal relation.
In addition to these studies, the one longitudinal study that examined dietary intake as a predictor of EF (Nyaradi et al., 2014) found that youth who had “Western” diets that were high in fast food intake, fried foods, sugar sweetened beverages, and red meat at age 14 were more likely to have difficulty with working memory at age 17. Likewise, the study found that youth with higher fruit consumption at age 14 had better working memory at age 17. Although this study considered gender, maternal education, and family functioning as covariates, it did not account for BMI. Therefore, it is difficult to know whether this relation would hold if weight status were considered. Taken together, results from Nyradi et al. (2014) and from Stautz et al. (2016) lend support to the idea that working memory may be bi-directionally related to dietary intake, given that Stautz and colleagues (2016) found that working memory predicted fruit and vegetable consumption when overall intelligence was not included in the analyses. Nevertheless, more research is needed to investigate the relation between EF and dietary intake over time.

Despite the overall mixed findings from observational studies of EF and dietary intake in youth, results from intervention studies were more definitive. Across domains and age ranges there was little evidence for an impact of short-term dietary interventions on subsequent EF. The interventions identified in this review targeted various aspects of diet, from specific micronutrients (i.e., fatty acids, glucose) to overall glycemic load. However, only two interventions (Mohd Taib et al., 2012; Whyte et al., 2016) found a significant relation between short-term manipulation of dietary intake and subsequent EF. One possible explanation for this finding is that there is a critical period across development during which dietary intervention has the most impact on cognitive functioning, likely when a child is very young (Walker et al., 2011). For example, Mohd Taib et al. (2012) included children under the age of 5, which may have contributed to the efficacy of the intervention. However, Whyte et al. (2016) included
children up to age 10, likely beyond the critical period, but this intervention represented the only study that examined the impact of wild blueberry supplementation. Therefore, it is possible that this type of nutritional intervention is more effective in the short term than interventions seeking to change other aspects of dietary intake. With regards to the timing of the interventions, both Mohd Taib et al. (2012) and Whyte et al. (2016) used cross-sectional designs in which EF was measured only hours after dietary intake were manipulated, whereas many of the other dietary interventions in this review did not find an effect even when the intervention lasted for months. This lends support to the influence that factors other than the length of the intervention, such as intervening during a critical period in development, have on efficacy.

In addition to concerns about developmental timing of dietary interventions, it is also important to note that all of the studies in this review focused on healthy children. There is an extensive literature demonstrating the micronutrient supplementation in children who are malnourished may be effective well past the age of five (Lam & Lawlis, 2017). It is possible that for healthy children, small alterations in dietary intake, especially at the nutrient level, may not impact EF due to a ceiling effect. Furthermore, given that many interventions used dietary supplements to alter nutrient intake, it is possible that dietary supplementation is not as effective as changing diet in healthy youth to impact EF. Although this review did not evaluate studies that examined the impact of fasting versus eating a meal on subsequent EF, a recent review by Adolphus and colleagues (2016) evaluated the impact of eating breakfast on cognitive functioning and found that eating something was better for cognitive functioning than eating nothing. Findings from Adolphus et al. provide evidence that, even in healthy children, fasting impacts cognitive functioning, mirroring the literature on cognitive functioning in malnourished children.
Finally, in contrast to the finding that short-term dietary intake interventions appear to have little impact on EF, two studies (Ames et al., 2016; Folkvord et al., 2016) found that training EF may impact dietary intake. Both studies found that interventions targeted at improving inhibition decreased consumption of unhealthy food (i.e., candy and SSBs). However, Folkvord et al. (2016) found more efficacy for the use of a go/no-go task than the Ames et al. (2016) study, which found that the use of a go/no-go task was only effective if combined with an “intention intervention” where participants had to write out statements detailing that they would resist against SSBs. However, given that neither study utilized a follow-up to determine whether there was a long-term effect of decreased unhealthy food consumption once participants left the lab, it is difficult to make firm conclusions about the findings. Additionally, although very few studies have evaluated the impact of EF training on dietary intake in youth, a large-scale review found that the effectiveness of such interventions was equivocal when evaluated across the lifespan (Jones et al., 2018). Therefore, more research should be conducted to examine the efficacy of EF training on improving dietary intake.

**Strengths and Limitations**

This is the first systematic review, to our knowledge, to integrate both cross-sectional, longitudinal, and intervention studies using a developmental lens to examine how EF and dietary intake may be differentially associated with one another across childhood and adolescence. Other strengths include the systematic study selection and review process, the wide variety of ages included, and the involvement of two independent researchers to conduct coding for results extraction. In terms of strengths of the existing literature, most studies accounted for demographic factors such as age, gender, and SES, which may have a confounding impact on both EF and dietary intake.
In addition to strengths, the literature on EF and dietary intake must also be evaluated in light of certain limitations. As previously stated, most of the studies in this review were not longitudinal, therefore it is impossible to infer directionality. The four longitudinal studies in this review shed light on the complicated nature of the relation between both EF and dietary intake, but only examined this relation during adolescence, therefore it is difficult to generalize to younger children. Also, as previously discussed, the measures used to assess EF and dietary intake were inconsistent across studies. For example, given that the domains of EF are distinct but related, most tasks that aim to measure only one component of EF likely require the use of other domains (e.g., a task of inhibition that requires working memory to keep track of the rules), but exactly which components of EF are required may vary across tasks. Additionally, all four studies in this review that measured EF as a unitary construct used the same child-report measure (the BRIEF-SR) to derive the overall EF score, whereas across all of the three other domains of EF (inhibition, working memory, and cognitive flexibility) most studies utilized objective, often computerized tasks to measure EF. Despite the well-established reputation of the BRIEF-SR, previous research has shown that self-reported problems with daily EF may measure a different underlying construct than computerized, more objective EF tasks (Toplak, West, & Stanovich, 2013), making it difficult to contextualize the findings. With regards to dietary intake, measurement ranged from lab-based food tasks to child-report dietary recalls. Although many studies used self-report assessments to measure dietary intake, such as a 24-hour dietary recall, is problematic given the inherent unreliability of such measures is also problematic (McPherson et al., 2000). Additionally, the dietary interventions included in this review were largely inconsistent in terms of both dietary intake variables (e.g., the length of the intervention, the type of dietary manipulation used) and the EF outcome measured, and there were only two
interventions included in this review that sought to train EF and subsequently measure dietary intake. Finally, given the increasing literature supporting a relation between EF and obesity, it should be noted that most studies in this review did not account for child weight, which may have confounded some of the results. Although most of the intervention studies included in this review determined no significant differences between initial BMI in the intervention as compared to the control group, only one of those studies examined BMI as a measure of the effectiveness of the intervention (Brindal et al., 2013), and no studies investigated BMI as a moderator to determine whether children with higher BMI may respond differently to the intervention. Overall, across all studies, most of those that did account for child weight still found a significant relation between EF and dietary intake. This lends support to the idea that the relation between EF and dietary intake may exist even for children without obesity.

**Future Directions**

Future research should examine EF and dietary intake from a longitudinal perspective to further clarify the directionality of the relation between the two. Furthermore, the longitudinal impact of EF on dietary intake should also be considered across different age ranges, not just during adolescence, to determine if changes in both variables may be different for both children (pre-puberty) and older teenagers. Additionally, given the increasing emphasis in the literature on “hot” vs. “cool” EF (see Zelazo & Carlson, 2012 for a review), future studies should investigate the relation between EF and dietary intake using the “hot” and “cool” model in light of the current criticisms against it (e.g., Gladner & Figner, 2014). This would shed light on whether EF is differentially associated with dietary intake inside and outside of the context of emotion (if it is determined that removing emotion from the equation is even possible).
Finally, consideration of the role of EF development should also be extended to work examining the relation between EF and childhood obesity to help inform interventions. EF training interventions often aim to treat obesity by improving inhibition or reducing attentional bias to food cues to improve dietary intake (Jones et al., 2018). Despite these goals, the results of EF training efforts have been mixed, and as seen in this review, very few interventions have evaluated the impact of EF training in children. Furthermore, those that attempt to improve inhibition and reduce receptivity to food cues do not necessarily translate to actual reductions in dietary intake outside of the lab (Jones et al., 2018). However, most of the existing research on EF training has been conducted in adults. Given that there is some evidence that EF may be associated with dietary intake for some children, future studies should investigate whether EF training may be effective in helping to prevent and treat childhood obesity.

Conclusion

This review identified that while there is some evidence of an association between EF and dietary intake in youth, the findings are mixed. Given that the association between EF and dietary intake is unclear and the directionality between the two is even less clear, more longitudinal studies are needed. Currently, there is minimal evidence that short-term interventions aimed at targeting aspects of dietary intake have an impact on EF, but little is known about whether the effectiveness of those interventions may differ by weight status. Furthermore, more studies are needed to evaluate whether EF training may help to improve dietary intake in across youth and whether those improvements may translate to actual eating patterns outside of the lab. In conclusion, the findings from this review emphasize the need to more consistently define and measure EF as well as to consider the role of development when evaluating EF and its relation to both dietary intake and obesity in youth.
CHAPTER THREE
THE HEAT IS ON: A MIXED-METHOD EXAMINATION OF EATING BEHAVIOR AND EXECUTIVE FUNCTION AMONG LOW INCOME MINORITY GIRLS DURING SUMMERTIME

Child obesity rates have tripled over the past 40 years (Ogden, Carroll, Kit, & Flegal, 2012), and low-income minority girls are disproportionately affected (Ogden, Carroll, Fryar, & Flegal, 2015). Rates of weight gain among youth are two to three times greater during the summer months than the rest of the year (Moreno, Johnston, & Woehler, 2013; Moreno et al., 2015; von Hippel & Workman, 2016), and may be particularly problematic among minority youth and youth who are already overweight (von Hippel, Powell, Downey, & Rowland, 2007). During the summer, when most children are not in a structured school setting, researchers have speculated that youth may engage in more obesity-related health behaviors, such as low levels of physical activity (McCue, Marlatt, Sirard, & Dengel, 2013), short sleep (Nixon et al., 2008; Bates et al., 2016), and high caloric intake (Baranowski et al., 2013). Although dietary intake has been proposed as a potential mechanism for weight gain over the summer months, few studies have tested this hypothesis empirically. Of the two studies that have examined summertime patterns of dietary intake in comparison with the school year, one found a modest increase in calorie consumption during the summer in Greek children ages 3-18 (Yannakoulia, Drichoutis, Kontogianni, & Mgkanari, 2010), and the other found no difference in calorie consumption in U.S. children ages 9-11 (McCue et al., 2013). A third study examined summertime dietary intake...
in second and third grade U.S. children participating in organized summer activity versus those who did not participate in organized activity and found that those who were involved in organized activity were more likely to eat breakfast and less likely to have meals in front of the television (Tovar et al., 2010). These eating patterns may be particularly problematic for low-income youth, who are less likely to be involved in organized activity during the summer than higher-income children (Chin & Phillips, 2004).

In addition to dietary intake, changes in structured activity that occur during the summertime may be problematic for other reasons. In general, the summertime is characterized by later sleep onset and wake times (Nixon et al., 2008) which may be associated with increased hours of daylight (Bénéfice, Garnier, & Ndiaye, 2004). In a previous examination of sleep among urban minority youth, Bates and colleagues (2016) found that average time of sleep onset during unstructured summertime was around midnight and average wake time was around 9:00am. Given that the average school start time (and thus average wake time) for an adolescent is typically before 9:00am (Wolfson, Spaulding, Dandrow, & Baroni, 2007), this change in sleep alone represents a significant shift in scheduling when transitioning to summertime. These schedule changes may shift food consumption timing to later in the day (Miller, Lumeng, & LeBourgeois, 2015), which is problematic given that increased calorie consumption at night has been associated with obesity (Gallant, Lundgren, & Drapeau, 2012). However, no studies to our knowledge have examined summertime dietary intake while taking into consideration timing of meals. Additionally, there is a lack of research examining the likelihood that some children may be more vulnerable to shifts in summertime schedules due to individual differences, such as difficulty with inhibition and cognitive flexibility (i.e., executive function).
Executive function (EF) represents cognitive processes involved in effortful and goal-directed behavior (Best, 2010), which have important connections to self-regulation, academic achievement, and successful functioning across activities of daily life (Li, Dai, Jackson, & Zhang, 2008; Mischel et al., 2011). Evidence consistently supports links between EF and sleep, such that children who are poor sleepers have more difficulty with impulsivity, working memory, and attention (Sadeh, Gruber, & Raviv, 2002). Additionally, even temporary sleep deprivation has been linked to impairments in EF in children (Sadeh, Gruber, & Raviv, 2003).

Relations may also exist between EF and dietary intake. For example, inhibition, the ability to suppress a dominant response, is linked to higher consumption of both energy dense, nutrient poor foods and sugar-sweetened beverages (Ames et al., 2014; Nederkoorn et al., 2015). Cognitive flexibility, the ability to respond to changing instructions and to shift behavioral goals (Ravizza & Carter, 2008), may also play a role. Prior studies have shown that, like inhibition, poor cognitive flexibility is related to a number of problematic eating behaviors, such as binge eating (Ames et al., 2014; Mobbs, Iglesias, Golay, & Van der Linden, 2011). In addition, Khan and colleagues (2015) found that problems with cognitive flexibility in seven-to-ten year olds were related to increased saturated fat and dietary cholesterol intake.

Although there are known links between EF and both dietary intake and sleep, little research has been done to examine associations between EF and meal times more broadly. Likewise, no studies to date have examined the interplay between later sleep onset, dietary intake, and EF. Utilizing a mixed-methods approach, the current study sought to evaluate the association between EFs and dietary intake in the summertime, taking into consideration the role of sleep and meal timing, among a sample of low-income minority females during early adolescence. Building on past research, we hypothesized that girls with more problems with EF
would consume more calories and have higher sugar consumption. We expected that girls who stayed up later at night would also have impaired EF, especially in the domain of inhibition. Given the lack of literature on associations between individual differences in EF and schedule changes, we conducted exploratory analyses to investigate a possible relation.

Method

Participants and Procedure

This study included 79 girls ranging in age from 9-13 years (M = 11.89, SD = 1.07 years). The majority of participants were African American (58%) or Latina (30%). Of participants who reported income, approximately 89% qualified for free or reduced lunch based on household income-to-needs ratio. Data for the current study was originally collected for a larger investigation evaluating the effectiveness of a four-week community-based summer program focused on promoting wellness and physical activity. Data were collected during the first weeks of the summer vacation period, prior to the start of a community-based program. Both programmatic and informed parental consent were obtained, and children provided verbal assent to participate in the study. Across all three summers of data collection, there were 97 unique participants. Fifteen participants did not complete full dietary intake recalls, and three participants were removed because they were outliers, reporting overall calorie consumption greater than 5000 kcal (approximately two standard deviations above the mean), bringing the total to 79.

In addition to the early adolescents, a subset of fourteen parents of participants, all mothers, also participated by completing a semi-structured qualitative interview about summertime eating patterns. All parents of participating girls were offered the opportunity to participate in qualitative interviews, and the 14 described here represent those who agreed.
Measures

Anthropometrics. Weight (measured using a digital scale to the nearest 0.1 kg) and height (measured using a SECA stadiometer to the nearest 0.1 cm with head held in the Frankfort plane) were used to calculate BMI (kg/m²). BMI z-scores were then calculated using age- and gender-specific CDC growth charts. (Centers for Disease Control and Prevention, 2015).

24-hour dietary recall. The triple-pass 24-hour dietary recall method was used to assess dietary intake, a process that aided participants in recalling everything they ate and drank within the preceding 24-hours. Recall information was entered into the University of Minnesota Nutrition Data System (NDS), and composite scores were calculated. For the purposes of the current study, total kilocalories, total grams of saturated fat, and total servings of fruit, vegetables, and SSBs were used for all dietary intake analyses. Time of food intake was also analyzed by taking an average of calories consumed by all participants within each hour. Following previous research, participants were classified as night eaters if they consumed more than 25% of their daily calories after 8pm (Allison et al., 2010).

Delis-Kaplan Executive Function System (D-KEFS). The D-KEFS Color-Word Interference Test (CWIT; (Delis, Kaplan, & Kramer, 2001) was utilized to measure inhibition and cognitive flexibility. Two of the four task conditions were used for the current study, in which the participant must (1) inhibit automatic responses by naming the color of words’ ink rather than reading the words (inhibition score), and (2) switch between naming ink color and reading words (cognitive flexibility score). For the purposes of the current study, the amount of time in seconds that it took a participant to complete the inhibition and the inhibition/switching conditions was recorded with more time on each indicating worse performance. These raw scores were used in all analyses. The CWIT evidences strong psychometric properties with internal
consistency coefficients ranging from 0.62 to 0.77 for children 10-to-14 years of age, and test-retest reliability ranging from 0.77 to 0.90 across conditions (Delis et al., 2001; Delis, Kramer, Kaplan, & Holdnack, 2004).

**Behavior Rating Inventory of Executive Function, Self-Report (BRIEF).** The BRIEF (Guy et al., 2004), a 55-item questionnaire measure of daily executive function, was also utilized to measure participants’ own perceptions of their executive function abilities. Raw scores from the Inhibit and Shift subtests of the BRIEF were used to measure self-reported problems with inhibition and cognitive flexibility in daily life, with higher scores indicating more problems. Previous examination of the psychometric properties of the BRIEF subscales has demonstrated good internal consistency ($\alpha = .72-.96$) (Guy et al., 2004). Cronbach’s $\alpha$ in the current study was .81.

**Semi-structured interviews.** A subset of parents completed a semi-structured interview regarding family eating patterns. Parents responded to the following question: “*How do your family’s eating patterns and mealtimes look different in the summer months as compared with the school year?*” followed-up with additional questions including: “*When and where does your child tend to eat?*” and “*What does your child tend to eat?*” Twelve interviews were conducted in English and two interviews were conducted in Spanish with fluent research assistants (RAs). Interviews were audio recorded and then transcribed and translated if necessary. A coding team (C.B., D.M.) read interview responses from all participants and extracted repeated themes (i.e., codes). Once all codes were determined, two RAs coded the same interview independently, and a Kappa value of .67 was computed. Following this coding, the RAs met together with the fourth author (D.M.) to discuss any discrepancies in coding and to clarify coding categories. Next, two additional interviews were coded, at which point the RAs reached 100% reliability ($K=1.0$).
Finally, the remaining 11 interviews were divided between the two RAs and coded. Once coding was complete, counts were taken for the number of times that each theme was mentioned across all interviews.

**Sleep.** Sleep patterns were measured via a waist-worn accelerometer (Actigraph GT3X; Pensacola, FL) positioned just behind the right hip, worn by participants for 1 week. For data processing, 60-s epochs of motion were used. Sleep variables were derived using algorithms created by Tudor-Locke and colleagues (2013), which are adapted from the Sadeh algorithm (Sadeh, Sharkey, & Carskadon, 1994), to better differentiate periods of sleep from periods of sedentary and non-wear time using waist-worn accelerometers (Barreira et al., 2015). For the current study, participants were required to have at least three nights of captured sleep to be included in analyses. Using data from all available nights, the current study examines sleep onset time, or the first minute of sleep at night, and nightly sleep duration, or the number of minutes scored as sleep between sleep onset time and wake time.

**Statistical Analysis**

All data were analyzed using IBM SPSS software, Version 22. Descriptive statistics were used to characterize participant dietary intake (i.e., average daily kilocalories, grams of saturated fat, servings of SSBs, fruit, and vegetables). Hierarchical linear regression models were used to assess for associations between EF and each of the five dietary intake variables. Both the D-KEFS and the BRIEF were entered as the independent variables into all models using forward regression to determine which measure of EF was most strongly associated with reported dietary intake. Exploratory independent samples t-tests and logistic regression models were then used to assess for differences in dietary intake and EF between participants who ate late at night and those who did not. A separate logistic regression model was used to assess for associations
between EF and timing of meals using sleep as a covariate. Due to its correlation with scores on the BRIEF and D-KEFS, participant age was entered as a covariate in all regression analyses. However, because zBMI was not significantly correlated with any of the other variables, it was not included in further analyses.

**Results**

Means and correlations are presented in Table 2. Average zBMI fell within the healthy weight range (M=1.04, SD=1.01) (Kuczmarski et al., 2000). Specifically, 1% (n = 1) of participants were underweight, 41% (n = 32) were healthy weight, 25% (n = 20) were overweight, and 33% (n = 26) were obese (Centers for Disease Control and Prevention, 2015).

Dietary recall data revealed that participants reported consuming between 25-35% more daily calories than the USDA (2015) recommended intake for a 9-13-year-old girl engaging in light physical activity. In addition, participants reported consuming less than the USDA (2000) recommended servings of vegetables per day (two vs. three), and more than the recommended servings of fruit (three vs. two). Furthermore, participants endorsed consumption of a SSB each day, on average.

**EF and Dietary Intake**

Hierarchical linear regression analysis examining the relation of EF with respect to dietary intake revealed that BRIEF Inhibit scores were significantly associated with total reported kilocalorie consumption, $F(1,69) = 5.39, p = .02, \beta = .27, R^2 = .07$, such that more reported problems with inhibition were related to higher calorie consumption. Similarly, accounting for age, D-KEFS inhibition time was also significantly associated with dietary intake, such that children who had more difficulty with inhibition (as evidenced by spending more time on the CWIT) also reported consuming larger amounts of sugar-sweetened soft drinks, $F(1,67) =$
6.25, $p = .02$, $\beta = .33$, $R^2 = .09$. However, there were no associations between cognitive flexibility measures and dietary intake.

**Meal Timing**

Meal timing was also evaluated. Participants consumed most of their calories between noon and 7:00PM. The largest number of calories consumed occurred during the 12:00PM hour ($m = 593$ kcal) and during the 7:00PM hour ($m = 531$ kcal). An average of 552 kcal were consumed after 8:00PM and before 6:00AM (i.e., night eating). More than one third of participants (38%) consumed more than 25% of calories after 8pm and were classified as night eaters. Chi-square analyses revealed no demographic differences between night eaters and daytime eaters. Independent samples t-tests examining differences between night eaters and daytime eaters revealed dietary differences between the two groups, such that night eaters reported consuming more sugar-sweetened soft drinks ($M=0.99$ servings, $SD=1.29$) than daytime eaters ($M=0.35$ servings, $SD=0.61$), $t(75) = -2.49$, $p = .02$. However, there were no other differences in reported consumption or BMI between night eaters and daytime eaters. T-tests also revealed that inhibition was more impaired in night eaters, who had greater total inhibition time on the D-KEFS ($M=78.72$ seconds, $SD=21.00$) than daytime eaters ($M=67.30$ seconds, $SD=17.12$), $t(77) = -2.63$, $p = .01$. However, there were no other differences in EF between daytime eaters and night eaters.
Table 2. Correlations and Descriptive Statistics of Measured Variables for Summertime Eating Patterns among Minority Youth

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2. zBMI</td>
<td>.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Kilocalories</td>
<td>.05</td>
<td>.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Saturated Fat</td>
<td>.04</td>
<td>-.11</td>
<td>.82**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5. Fruit</td>
<td>-.08</td>
<td>.05</td>
<td>.04</td>
<td>.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Vegetables</td>
<td>.05</td>
<td>.01</td>
<td>.09</td>
<td>.07</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Soft Drinks</td>
<td>-.08</td>
<td>.04</td>
<td>.04</td>
<td>.01</td>
<td>0.0</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. D-KEFS Inhib</td>
<td>-.39**</td>
<td>.17</td>
<td>-.07</td>
<td>-.15</td>
<td>-.01</td>
<td>-.08</td>
<td>.23*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. D-KEFS In/Sw</td>
<td>-.22</td>
<td>.18</td>
<td>-.02</td>
<td>-.03</td>
<td>-.15</td>
<td>-.11</td>
<td>.06</td>
<td>.59**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. BRIEF Inhibit</td>
<td>-.05</td>
<td>.09</td>
<td>.21</td>
<td>.14</td>
<td>-.01</td>
<td>-.04</td>
<td>-.01</td>
<td>0.06</td>
<td>-.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. BRIEF Shift</td>
<td>-.24*</td>
<td>.05</td>
<td>-.04</td>
<td>-.10</td>
<td>-.003</td>
<td>-.05</td>
<td>-.08</td>
<td>.13</td>
<td>-.05</td>
<td>.39**</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>11.92</td>
<td>1.04</td>
<td>1994.48</td>
<td>27.30a</td>
<td>2.8b</td>
<td>1.89b</td>
<td>0.6b</td>
<td>71.63c</td>
<td>76.52c</td>
<td>6.43</td>
<td>7.02</td>
</tr>
<tr>
<td>SD</td>
<td>1.10</td>
<td>1.01</td>
<td>822.92</td>
<td>15.87</td>
<td>3.0</td>
<td>1.66</td>
<td>1.0</td>
<td>19.38</td>
<td>18.26</td>
<td>4.36</td>
<td>3.58</td>
</tr>
<tr>
<td>Range</td>
<td>9.88-</td>
<td>85.77-</td>
<td>4491.38</td>
<td>4.60-85.46</td>
<td>0-14.46</td>
<td>0-7.80</td>
<td>0-5.31</td>
<td>120</td>
<td>140.13</td>
<td>1-17</td>
<td>1-16</td>
</tr>
</tbody>
</table>

* p < 0.05  
**p < .01  
aGrams, bServings, cSeconds
Given the impairments in inhibition found in night eaters, logistic regression analyses were conducted to examine whether this relation would remain significant when accounting for the influence of sleep patterns. Analyses revealed that, after accounting for both sleep onset and duration, poor inhibition was positively associated with late night eating, $X^2(4) = 12.16, p = .016$.

**Qualitative Descriptions of Schedule Changes**

As can be seen in Table 3, qualitative data revealed that parents/guardians also noted changes in the timing of meals during the summer months. For example, 85.7% of parents indicated that their daughter ate different foods during the summer, with 71.4% of parents specifically indicating that their daughter ate more fruit. On the other hand, 21.4% of parents indicated that their daughter ate more food in general over the summer months (e.g., “*When they are home, they watch TV, they eat, they eat, eat, eat.*”). Meanwhile, timing of meals also seemed to be different during the summer: 50% of the parents indicated that their daughter ate at different times (e.g., “*She wakes up later, like at 12, so she isn’t hungry...*”). Parents also indicated that the flexibility of summertime increased the number of family meals, and 35.7% of parents indicated that the family ate dinner together more frequently. Although 28.6% of the parents indicated that the family cooked at home more, 21.4% indicated that the family cooked at home less during the summer when compared to the school year, citing the rise in temperatures (e.g., “*...90 degrees outside, I don’t want to get the kitchen all hot...*”).
Table 3. Qualitative Coding Themes and Counts of Summertime Family Eating Patterns

<table>
<thead>
<tr>
<th>Theme</th>
<th>Sub-theme/Code</th>
<th>Number of Parents who Mentioned in Response (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in eating patterns during the summer as compared to the school year</td>
<td>She eats more/is hungrier</td>
<td>3 (21.4%)</td>
</tr>
<tr>
<td></td>
<td>She eats at different times</td>
<td>7 (50.0%)</td>
</tr>
<tr>
<td></td>
<td>She eats different foods</td>
<td>12 (85.7%)</td>
</tr>
<tr>
<td></td>
<td>She eats more fruit</td>
<td>10 (71.4%)</td>
</tr>
<tr>
<td>Change in family meals during the summer as compared to the school year</td>
<td>Family eats dinner together more often</td>
<td>5 (35.7%)</td>
</tr>
<tr>
<td></td>
<td>Family avoids hot foods</td>
<td>4 (28.6%)</td>
</tr>
<tr>
<td></td>
<td>Family cooks more</td>
<td>4 (28.6%)</td>
</tr>
<tr>
<td></td>
<td>Family cooks less</td>
<td>3 (21.4%)</td>
</tr>
</tbody>
</table>

Discussion

The current study assessed summertime dietary intake patterns in a sample of low-income minority girls, in the context of EF, meal timing, and sleep. Results from this study suggest that overeating during the summertime may be problematic, with the average number of calories consumed between 25-35% higher than USDA recommended daily values for girls engaging in light physical activity. Additionally, this study also revealed that individual factors, such as EF (specifically, difficulty with inhibition), may be associated with poor dietary intake. Contextual factors, such as meal timing, were also relevant. Over one-third of participants consumed 25% or more calories between 8PM and 6AM. These participants had more difficulty with inhibition than those who did not eat late at night, even after accounting for sleep. They also reported consuming larger amounts of sugar-sweetened soft drinks.
This study is the first to our knowledge to demonstrate a link between late night eating and inhibition. Although prior studies have descriptively examined night eating in adolescents (Striegel-Moore et al., 2004), few studies have evaluated psychological correlates that are associated with late night eating in a nonclinical population. Furthermore, the current findings suggest that the inhibitory problems seen in late night eaters exist above and beyond what is explained by sleep schedules. Bates and colleagues (2016), drawing from a subsample of participants in the current study, demonstrated that minority girls had an average sleep onset time of 12:10 am when not in structured programming. However, our findings suggest that staying up late may not be the sole, or most important, factor relating to eating late. Instead, difficulty with inhibition also appears to be a key correlate of late night eating.

Although late night eating is not specific to summertime, the summer months may represent a time of schedule shifting, where staying up late is more likely. Furthermore, individual factors, such as poor inhibition, may explain why some children are particularly susceptible to engaging in less healthy dietary habits during the summer. In conjunction with the dietary recall data, qualitative data indicated the potential role of contextual factors (i.e., going to sleep late, watching more TV) that may explain summertime dietary habits. Research has shown that fewer household routines are associated with greater risk for child obesity (Bates et al., 2019; Anderson & Whitaker, 2010). Future work should consider summertime’s influence on family structure and routine as a potential mechanism influencing eating patterns and weight gain during this time.

The results of this study also demonstrate that only certain aspects of EF, specifically inhibition, are associated with problematic eating behaviors. This may help to explain why children may have the knowledge of which foods are healthy and which foods are not, but still
choose unhealthy foods (Heard, Harris, Liu, Schwartz, & Brownell, 2016). The findings of the current study contrast with those of Khan and colleagues (2015), who found that cognitive flexibility was significantly associated with saturated fat intake. However, Khan and colleagues used different tasks to assess cognitive flexibility and a younger sample of children (ages 7-10), both of which may partially account for these differences.

**Limitations and Future Directions**

This study is not without limitations, including that dietary intake was only assessed during the summer months, specifically during the first weeks of summer, without school-year comparisons. Future studies should compare dietary intake in the summer to the school year to determine whether there are significant changes that may help to explain summertime weight gain. Likewise, sample size was also limited in this study, especially for parent interview data. Because only a small percentage of parents agreed to be interviewed, selection bias may have influenced qualitative results for a few reasons. First, the parents that we interviewed were all interested in having their daughter participate in a health and wellness summer camp, and second, only a small proportion of eligible parents actually participated in the interviews. This may have impacted our findings. Although these interviews allowed us to collect important data about the ways in which summertime scheduling differed from that of the school year, information about the role that parents played in children’s schedules and dietary intake was not collected. This study used 24-hour recalls as the primary method of collecting information about dietary intake. Although short term 24-hour recalls are generally considered to be less error prone than food frequency questionnaires, limitations of self-report data still apply (Kipnis, Carroll, Freedman, & Li, 1999). In addition, the unique characteristics of this sample may limit generalizability of these findings. All of the participants in this study had signed up for a four-
week community-based summer program focused on promoting physical activity and wellness. Given their selection, it is likely that the participants in this study value health and may engage in healthier eating patterns. Finally, given the cross-sectional nature of this study, it is impossible to determine the directionality of the relation between EF and dietary intake.

Future studies should examine inhibition and diet from a longitudinal perspective to determine whether poor inhibition leads to late night eating and poor dietary intake, eating patterns impact inhibition, or if the relation is reciprocal in nature. These studies should examine dietary intake both during the summertime and during the school year to determine whether there are differences in scheduling, EF, and meal times across the year. Likewise, more research should be conducted on whether there are differences in inhibition between children who wake up in the middle of the night to eat and those who simply stay up late eating. Additionally, it is possible that in addition to EF, motivation and drive for food may also play a role in dietary intake. Future studies should assess both EF and drive to elucidate whether the two may work together to influence intake, or alternatively whether EF or drive plays a stronger role in influencing diet. Finally, given that EF only explained a small percentage of the variance in dietary intake, future research should continue to examine other factors that may also be associated with summertime food consumption.

**Conclusion**

This mixed methods study augments the current literature by being the first to examine summertime dietary intake from a contextual perspective, finding an association between meal times and inhibition by utilizing rigorous, objective dietary recall methodology alongside qualitative interviews. It also supports a growing literature that EF problems are related to unhealthy dietary intake in youth. Understanding the factors that may lead to obesity, especially
in ethnic minority populations, is important for creating effective interventions to prevent weight gain before it becomes a more intractable problem in adulthood.
CHAPTER FOUR: THE IMPACT OF UNHEALTHY FOOD MARKETING ON INHIBITION DURING ADOLESCENCE AND EMERGING ADULTHOOD: DISORDERED EATING AS A MODERATOR

Over the last decade, an increasing body of research has reported the high prevalence and highly effective nature of food marketing to children (e.g., (Federal Trade Commission (FTC), 2012; Kelly et al., 2016). There is evidence to suggest that children as young as age four prefer the taste of a food that comes in a McDonald’s package as compared to food wrapped in an identical, but unbranded package (Robinson et al., 2007). This finding has been replicated across age groups and seems to be consistent for other familiar food brands (McClure et al., 2004). The highly influential nature of food marketing has important public health implications, especially given that the majority of foods and beverages advertised on television are high in calories and low in nutritional quality (Powell et al., 2007). Despite the overall unhealthy nature of these foods, popular advertisements often contain messages that appeal to youth and assert that consumption is cool, fun, and associated with happiness (Folta, Goldberg, Economos, Bell, & Meltzer, 2006).

Food Marketing and Dietary Intake

Research suggests that food marketing not only influences preferences, but it also influences dietary intake (Harris, Pomeranz, Lobstein, & Brownell, 2009). Using large-scale epidemiological data, one study estimated that for every 100 commercials a child viewed for sugar-sweetened soft drinks, their consumption of soft drinks rose 10% (Andreyeva, Kelly, &
Harris, 2011). Experimental studies also echo these findings. Harris and colleagues (2012) found that after children viewed advertisements featured in food company branded computer games, they consumed more junk food and fewer fruits and vegetables than children who played computer games without marketing. There is also evidence that food marketing may also influence older youth. In addition to finding that exposure to unhealthy food marketing increased snack intake in children, Harris, Bargh, and colleagues (2009) also found that college students (ages 18-24) ate more snacks after watching unhealthy food ads than they did after watching either healthy food ads or non-food ads. Harris, Bargh, et al. represents one of the few studies that have examined the impact of food marketing on late adolescents and emerging adults. Taken together, although all of these findings have led public health advocates to assert that food marketing to children, especially those who are too young to understand the persuasive intent of marketing, should be limited (Harris, Pomeranz, et al., 2009), efforts to curb food marketing have largely focused on young children and failed to include adolescents and emerging adults (Harris, Heard, & Schwartz, 2014).

**Food Marketing and Inhibition**

From a developmental perspective, there is significant evidence that although the ability to understand the intent of an advertisement is developed by early adolescence, the skills needed to resist against the messaging contained in an advertisement may not be fully developed until adulthood (Friestad & Wright, 1994). These skills are, in part, represented by executive function (EF), defined as the cognitive processes involved in effortful and goal-directed behavior (Best & Miller, 2010). EF processes are largely controlled by the frontal lobe, which does not fully develop until the mid-twenties (Best & Miller, 2010). One key component of EF, inhibition, can be understood as the process of pursuing a more distant goal instead of an easier and more
automatic goal, and is thought to be especially salient in making healthier choices in the face of competing motivation (Fujita, 2011). However, few studies have examined the interplay between inhibition and unhealthy food marketing, especially during late adolescence and emerging adulthood, when there may be an awareness of the importance of eating nutritious foods while still being heavily influenced by the persuasive nature of unhealthy food advertisements (Harris et al., 2014).

Despite the lack of empirical research directly linking inhibition and food marketing, there has been plenty of discourse on the role of inhibition in making healthy food choices. This conversation has often used the term “self-control” instead of inhibition. In an article explaining the link between self-control and EF, Hofmann and colleagues (2012) define self-control as the cognitive processes used to override unwanted or unhelpful prepotent responses to urges. Inhibition is, then, inextricably linked to self-control, as it represents the act of choosing one response over a competing other (Hoffmann, Schmeichel, & Baddeley, 2012). Within the domain of food, much of the popular discourse on inhibition has focused on the role of personal responsibility. Food industry representatives have consistently argued in favor of Americans taking more responsibility, or exercising more self-control, over their diets while arguing against government regulation (Brownell et al., 2010). These thoughts also permeate society at large, which can be seen in the widespread stigma, bias, and discrimination faced by overweight individuals (Puhl, Andreyeva, & Brownell, 2008; Puhl & Heuer, 2009). They also fuel arguments that government intervention, such as taxes and portion size regulations on sugar-sweetened beverages, is indicative of a “nanny” state (Brownell et al., 2010). However, these personal responsibility arguments fail to take into account conditions in the modern food environment that make it difficult to achieve the proper energy balance to maintain a healthy
weight (Brownell et al., 2010). These things include larger portion sizes, more added sugar in food, and increased exposure to unhealthy food both in vivo and through advertisements (Brownell et al., 2010). Although there have been efforts to protect young children from the negative effects of the food environment (e.g., Council of Better Business Bureaus, 2016), adolescents and emerging adults have been largely omitted from the conversation.

Adolescents and emerging adults live in a food environment that is inundated with cues that signal the availability of energy dense, nutrient poor foods (Burton, Smit, & Lightowler, 2007). Some researchers have hypothesized that these cues may serve as reinforcers that lead to cue-elicited intake through classical conditioning (van den Akker, Jansen, Frentz, & Havermans, 2013). Adolescents may be inundated with real food, as found in fast-food restaurants, grocery and corner stores, or with images of food, as found in food advertisements on television, the internet, and social media, but there is evidence to suggest that both types of food cues may influence dietary intake. Indeed, a meta-analysis by Boswell and Kober (2016) found a medium effect size of the impact of food cues on eating behavior, such that exposure to images of food produced a similar effect as exposure to real food in contributing to subsequent food consumption. This has important implications for understanding the impact of food marketing, a large-scale environmental food cue, on dietary intake. Specifically, if exposure to food marketing elicits similar food consumption as exposure to real food does, it is possible that the role of inhibition in resisting food marketing may be similar to that of resisting real food. Given the pervasive nature of food marketing, it is possible that existing in the current food environment requires a near constant exercise of inhibition. According to theories of ego-depletion, this may be problematic, as an act of self-control in one instance may make it more difficult to exercise self-regulation in another instance (Baumeister, Bratslavsky, Muraven, & Tice, 1998). However,
ego-depletion theory has recently come under fire, and the results of both meta-analyses and replication studies lend little support to resource theories of self-control, like ego-depletion (Hagger et al., 2016; Lurquin et al., 2016). Given these disparate findings, Lurquin and Miyake (2017) asserted that in order to measure the impact that any stimulus, like food marketing, has on “self-control,” operational definitions and clear and consistent measures are needed (Lurquin & Miyake, 2017). One way to achieve this is to measure food marketing’s impact on formalized constructs, such as inhibition, instead of purporting to measure “self-control” more generally (Lattimore & Mead, 2015).

**The Role of Disordered Eating**

In addition to the need to measure the impact that environmental food cues, like food marketing, may have on inhibition, there is also evidence that some individuals may be more responsive to food cues than others. Specifically, individuals with disordered eating may be at risk. According to Fairburn’s transdiagnostic model, many eating disorders are perpetuated through an overemphasis on the importance of shape and weight that manifests through a pattern of dietary restraint and subsequent impulsive behavior, such as binge eating, in reaction to minor lapses in restraint (Fairburn et al., 2003). These traits have also been associated with increased dietary intake upon exposure to food cues during lab-based tasks. For example, impulsivity, the tendency to exhibit rapid and unplanned reactions to external or internal stimuli regardless of consequences (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001), has been associated with a greater tendency to overeat in response to in vivo food cues (Lattimore & Mead, 2015). van den Akker and colleagues (2013) found that individuals who scored higher in impulsivity on a self-report measure were also more likely to overeat in the lab when exposed to a virtual reality environment that contained stimuli associated with food. This is consistent with an extensive
literature illustrating that impulsivity is associated with both obesity (French, Epstein, Jeffery, Blundell, & Wardle, 2012), as well as disordered eating patterns (Claes, Nederkoorn, Vandercycken, Guerrieri, & Vertommen, 2006).

Dietary restraint, the other key feature of many eating disorders, has also been linked to increased food cue reactivity (Brunstrom, Yates, & Witcomb, 2004). In this context, highly restrained eaters are those who attempt to exercise rigid control over eating instead of relying on physiological cues to direct hunger, often attempting to maintain diets without success (Stice, Fisher, & Lowe, 2004). Research shows that dietary restraint is often related to overeating. For example, Harris, Bargh, and colleagues (2009) found that restrained eaters ate more food after being exposed to television commercials than non-restrained eaters. Likewise, there is evidence that dietary restraint and impulsivity may interact to enhance susceptibility to food cues. For example, Jansen and colleagues (2009) found that highly restrained eaters who were also high on impulsivity tended to overeat when presented with highly caloric foods in a lab based food task.

Given that both impulsivity and dietary restraint are hallmark features of many eating disorders, especially those that include binge eating (Claes et al., 2006), these findings suggest that individuals with disordered eating patterns may also be more vulnerable to increased food consumption when presented with food cues, in the form of either real food or food marketing. However, the association between disordered eating and response to food cues has gone largely unexamined in the clinical literature, representing a gap in our understanding of how the current food environment may impact those who struggle with disordered eating.

Although impulsivity is often present across eating disorders, there is evidence that it may be specific to food-related cues as opposed to more general cues. Like the term “self-control” there is evidence that “impulsivity” and inhibition are also highly related to one another
(Logan, Shachar & Tannock, 1997). One method for measuring impulsivity is through the use of a stop-signal task, in which individuals alternate between responding to a stimulus and inhibiting a response to a stimulus when instructed. During the task, inhibition becomes more difficult when participants must wait longer to determine if they will be told to inhibit response. Research suggests that individuals who are higher in impulsivity tend to perform worse on stop-signal tasks, as impulsivity represents a deficit in the ability to exercise inhibition (Logan et al., 1997). Consistent with this hypothesis, adults with disordered eating patterns generally perform worse than controls on stop-signal tasks using food images as stimuli; however, these deficits appear to be only food-specific, and there is little support that these individuals perform worse on stop-signal tasks that do not use food images as stimuli (Svaldi, Naumann, Trentowska, & Schmitz, 2014). Another common measure of inhibition, the Stroop task, has also been used in individuals with disordered eating. Consistent with results from stop-signal tasks, individuals with disordered eating tend to perform worse than controls on modified Stroop tasks, with stimuli related to food and body shape, but they tend to perform similarly to controls on classic Stroop tasks with neutral stimuli (Dobson & Dozois, 2004). Therefore, lab-based paradigms support clinical observation that individuals with disordered eating struggle with inhibition (Fairburn et al., 2003). However, past studies have investigated whether there is a main effect of disordered eating on performance on an inhibition task (by either using food stimuli or using neutral stimuli), but there is little research on whether individual differences in disordered eating may moderate the relation between exposure to food cues and performance on an inhibition task. Furthermore, little is known about the interplay between disordered eating, exposure to food marketing, and inhibition in adolescent and emerging adult populations. This is problematic given that rates of both disordered eating and food marketing exposure are high during
adolescence and emerging adulthood (Krahn, Kurth, Gomberg, & Drewnowski, 2005; Nelson et al., 2008).

The Current Study

The purpose of the current study was to elucidate mechanisms that link food marketing and unhealthy dietary intake. Using a within-subjects design, this study sought to investigate the impact of exposure to unhealthy food advertisements on inhibition during late adolescence, a vulnerable group that has been overlooked in food marketing research. This study assessed participants after having viewed both food commercials and non-food commercials to compare subsequent performance on an inhibition task. Consistent with previous research, the current study aimed to measure inhibition using (1) a measure of general inhibition (non-food stimuli), (2) a measure of food-specific inhibition (food stimuli), and (3) a measure of actual food consumption. Additionally, given evidence that individuals with disordered eating may be particularly susceptible to food marketing, the current study sought to examine the moderating impact of disordered eating on the relation between food marketing and inhibition in late adolescence. In order to capture multiple facets of disordered eating, the current study considered both overall transdiagnostic characteristics of disordered eating (i.e., dietary restraint, weight concerns, shape concerns, and eating concerns) as well as the endorsement of binge eating behaviors, due to their link to both impulsivity and dietary restraint (Fairburn et al., 2003).

Specific Aims and Hypotheses

1) Examine the impact of viewing unhealthy food commercials on performance on a general inhibition task. It is hypothesized that participants will experience more difficulty on a Stroop task (i.e., the D-KEFS) measuring inhibition (i.e., using non-food stimuli) after watching unhealthy food commercials compared to after watching non-food commercials.
2) *Investigate the impact of viewing unhealthy food commercials on performance on a food-specific inhibition task.* After participants watch unhealthy food commercials, it is expected that accuracy on a stop-signal task (i.e., using food stimuli) will be lower and stop-signal delay will be higher compared to after watching non-food commercials.

3) *Investigate the impact of responding to unhealthy food commercials on unhealthy food consumption during a lab-based food task.* It is anticipated that participants will eat more candy after viewing unhealthy food commercials compared to after viewing non-food advertisements.

4) *Assess the moderating role of disordered eating on the relation between responding to unhealthy food commercials and performance on a general inhibition task, a food-specific inhibition task, and a lab-based food task.* It is anticipated that participants who endorse more transdiagnostic characteristics of disordered eating (i.e., dietary restraint, weight concerns, shape concerns, and eating concerns) will perform worse on a food-specific inhibition task (i.e., have higher stop-signal delay and lower stop-signal accuracy), as compared with those who endorse fewer transdiagnostic characteristics of disordered eating. However, it is also hypothesized that transdiagnostic characteristics of disordered eating will not moderate performance on a Stroop-like task measuring general inhibition or consumption of candy during a lab-based food task. With regards to binge eating, it is anticipated that participants who endorse binge eating will perform worse on a food-specific inhibition task and will consume more during a lab-based food task after viewing food commercials than they will after viewing non-food commercials as compared with those who do not endorse binge eating. However, it is anticipated that binge eating will not moderate the relation
between commercial type and performance on a Stroop-like task measuring general inhibition task.

Method

Participants

Participants included were 44 undergraduate females ranging in age from 18-23 years old (mean age = 18.86, SD = 1.05) recruited from a pool of undergraduate students in psychology. Participants were pre-screened using a number of surveys assessing disordered eating, mood, and daily activity patterns, including television watching. Participants were invited to participate in the current study if they reported either high (75th percentile and above) or low (25th percentile and below) transdiagnostic characteristics of disordered eating, as measured by the Eating Disorder Examination-Questionnaire (EDE-Q; Fairburn & Beglin, 1994) to ensure sufficient variability to measure differences in levels of disordered eating. Males were excluded from this study due to the high levels of eating disorders among women (Hudson, Hiripi, Pope, & Kessler, 2007) and because many of the most commonly used measures of eating disorders have not been normed and validated on males (Berg, Peterson, Frazier, & Crow, 2012). Because participants in this study also completed measures that assessed neural response to food cues as part of a secondary study, all participants were also right-handed. All 44 participants in the study completed the stop-signal task. However, scaled scores for the general task of inhibition (the D-KEFS) could only be calculated for 43 participants due to one participant failing to provide her exact birthdate, and 41 participants completed the lab-based food task due to a malfunction of study equipment. Therefore, the analysis for the various study measures reflect slightly different total samples.
Procedure

This study was pre-registered on the Open Science Framework: www.osf.org. Participants were brought into the lab either between 10am-1pm and instructed to eat breakfast before they arrived or tested between 1-5pm and told to eat lunch before they arrived to minimize initial differences in hunger. Upon arrival to the laboratory, participants completed several assessments, including a short mood assessment embedded with questions about hunger to assess for satiety without alerting participants to the purpose of the study. If participants endorsed significant hunger levels, they were offered a granola bar before beginning the task.

This study utilized a two-condition within-subjects design, such that participants were tested in the laboratory two times, at least one week apart (M = 11 days, SD = 6 days). During one session, they were shown five advertisements for unhealthy foods and during the other session, they were shown five advertisements for non-food items. The order of presentation of the food or non-food advertisements was counterbalanced across participants. Commercials that appeared frequently on women’s programming were selected for this study from a sample of 20 total commercials (10 food and 10 non-food). These commercials were pretested using an online sample of women between the ages of 18-25 who assessed the valence (i.e., how appealing it was) and arousal (i.e., how much emotion it evoked) of each commercial on a 1-7 scale. Next, the valence and arousal of the food and non-food commercials was compared. T-tests indicated that there were no differences in arousal, t(318) = 0.56, p = .58, or in valence between the food commercials and the non-food commercials, t(318) = 1.28, p = .20. The top five most appealing commercials (highest in valence) were chosen in both the food and the non-food categories (see Table 4). For a detailed description of the pre-testing of the commercials considered for this study, see Chapter Six.
### Table 4. Characteristics of Food and Non-Food Commercials

<table>
<thead>
<tr>
<th>Commercial Type</th>
<th>Brand</th>
<th>Type of Product</th>
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<tbody>
<tr>
<td>Food</td>
<td>Diet Coke</td>
<td>Soda</td>
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<tr>
<td>Food</td>
<td>Pizza Hut</td>
<td>Fast Food</td>
</tr>
<tr>
<td>Food</td>
<td>Kit-Kat</td>
<td>Candy</td>
</tr>
<tr>
<td>Food</td>
<td>Dove Chocolate</td>
<td>Candy</td>
</tr>
<tr>
<td>Food</td>
<td>Starbucks</td>
<td>Sugar-sweetened coffee drink</td>
</tr>
<tr>
<td>Non-Food</td>
<td>Always</td>
<td>Feminine Product</td>
</tr>
<tr>
<td>Non-Food</td>
<td>Amazon Echo Dot</td>
<td>Technology</td>
</tr>
<tr>
<td>Non-Food</td>
<td>Degree Deodorant</td>
<td>Deodorant</td>
</tr>
<tr>
<td>Non-Food</td>
<td>Ulta Beauty</td>
<td>Makeup</td>
</tr>
<tr>
<td>Non-Food</td>
<td>Volkswagen</td>
<td>Car</td>
</tr>
</tbody>
</table>

After watching the commercials, participants were instructed to complete a written response detailing the tactics that the commercials used to persuade them to buy the products and reasons why they should not buy the products. Next, participants completed two tasks to assess inhibition (food/non-food stimuli). After completing both tasks, participants were told that the examiner had to leave the room to get one last set of surveys, at which point the lab-based food task began. Before exiting the room, the examiner left a divided bowl of M&M and Skittles candy (one on either side) in the room and told the participant to have as much of the candy as she would like while she waited for the examiner to return. The examiner was also instructed to take a handful of candy before leaving the room and to record the exact amount of candy taken once out of view of the participant. Participants were left in the room alone for two minutes, after which time the experimenter returned to the room with surveys for the participants. On the first visit, participants completed questionnaires assessing mood and eating habits. On the second visit, participants completed one questionnaire assessing mood. While participants completed surveys, the experimenter removed the bowl of candy from the room so that it could be weighed.
Bowls of candy were weighed before and after the food task to determine the amount of candy taken by the participant (each piece of candy weighed 1 gram). Finally, after completing surveys, height and weight were measured using a scale and stadiometer.

**Measures**

**Demographics.** Demographics, including age, were assessed via self-report questionnaire.

**Body mass index.** Height was collected during the first visit to the lab, at the completion of all other tasks. Weight was collected during both the first and second visits to the lab, after the collection of height. Weight was measured to the nearest 0.1 kilogram (kg) and height was measured to the nearest 0.1 centimeter. BMI was calculated using the standard formula of kg/meters$^2$. For the purposes of the current study, Time 1 BMI was used to descriptively evaluate participants.

**Disordered eating.** The Eating Disorder Examination-Questionnaire (EDE-Q; Fairburn & Beglin, 1994), a 28-item measure assessing the features of disordered eating, was used to measure disordered eating. The EDE-Q is the self-report version of the Eating Disorder Examination (EDE), a semi-structured interview used to diagnose eating disorders. The EDE-Q has four subscales: (1) restraint, (2) shape concerns, (3) weight concerns, and (4) eating concerns and one global score, calculated as the sum total of all subscales divided by four. Participants rated each item on a scale from 0-6 on how many times they have acted in a certain way over the past 28 days (0 = no days; 6 = every day) or how much they have felt a certain way over the past 28 days (0 = not at all; 6 = markedly). Items comprising each subscale include, “have you been deliberately trying to limit the amount of food you eat to influence your shape or weight, whether or not you have succeeded?” (restraint); “has your shape influenced how you think about (judge)
yourself as a person?” (shape concerns); “has your weight influenced how you think about (judge) yourself as a person?” (weight concerns); and “has thinking about food, eating, or calories made it very difficult to concentrate on things you are interested in?” (eating concerns). The EDE-Q global score, a combination of scores on all four subscales, was used to measure transdiagnostic characteristics of disordered eating. As previously mentioned, participants were classified as having either a high EDE-Q global score (75th percentile or higher) or a low EDE-Q global score (25th percentile or lower). The EDE-Q has been found to have good reliability ($\alpha = .90$) (Peterson et al., 2007).

In addition to measuring transdiagnostic characteristics of disordered eating, the EDE-Q also assesses the frequency of binge eating behaviors (e.g., eating an unusually large amount of food, experiencing a loss of control over eating, etc.) in the past 28 days by asking participants to fill in the number of times that each behavior occurred. In addition to classifying participants as having a high or low EDE-Q global score, participants were also sorted based on whether they reported binge on item 15 of the EDE-Q “…on how many days have such episodes of overeating occurred (i.e., you have eaten an unusually large amount of food and have a sense of loss of control at the time?)” Participants were classified as endorsing binge eating if they reported having such an episode on one or more days. Given that the EDE-Q global score does not include questions specific to binge eating, the two classifications of disordered eating were not mutually exclusive, such that an individual who endorsed binge eating did not necessarily have a high EDE-Q global score and vice versa.

**Hunger.** To ensure that participants were not hungry prior to beginning the experiment, hunger was assessed by adding an additional item to the standard Positive and Negative Affect Scales (PANAS; Watson, Clark, & Tellegen, 1988). Consistent with previous research,
participants indicated their level of hunger on a scale from 1 (very slightly or not at all) to 5 (extremely) (Harris, Bargh, et al., 2009). This score was then checked before the experiment began to ensure that participants were not hungry (i.e., that they rated hunger as less than 4 on the 1-5 scale) before beginning the task.

**General inhibition.** The Delis-Kaplan Executive Function System Color-Word Interference Task (D-KEFS CWIT) (Delis et al., 2001) was used to test general inhibition. The CWIT is a Stroop task that requires individuals to inhibit a dominant response (reading a word) in favor of completing a less automatic action (naming the color of the word). For the purposes of the current study, response time on the inhibition subscale of the CWIT was used, with greater response time indicating worse inhibition (Delis et al., 2004).

**Food-specific inhibition.** A computerized stop-signal task was used to test food-specific inhibition. For this task, digitized food images were obtained from the Food-pics database (Blechert, Meule, Busch, & Ohla, 2014), an open source database of pre-screened food images. Fifty-two healthy and 52 unhealthy food images were chosen and were then matched on valence and arousal. In the stop-signal task, food images were presented on a computer screen, and participants were instructed to choose whether the images were healthy or unhealthy. On *go trials* (see Figure 4) participants were asked to press a button to indicate whether images are healthy or unhealthy. Participants were first presented with a blank screen containing a fixation cross. Next, a food image appeared on the screen for 1s and participants were instructed to press one of two buttons on an electronic response box to indicate healthy or unhealthy. Participants were given up to 1s to make a selection. On *stop trials* (see Figure 4) a stop signal (a black and white striped box surrounding the food stimulus) was presented for 100ms immediately after the onset of the food stimulus. Participants were instructed to withhold making a response (i.e., a
choice of whether the image is healthy or unhealthy) when they saw the stop signal. In this task, performance on stop trials represented the food-specific measure of inhibition. In order to standardize difficulty across participants, the delay between the food stimulus presentation and the stop signal was adjusted (200-500ms). Thus, participants who were successful in withholding their responses on the previous two stop trials had a 20ms longer stop delay on the third trial, making the task slightly more difficult. The better a participant performed on stop trials, the longer the delay between presentation of the food stimulus and presentation of the stop signal. This allowed for calibration of response inhibition effort across participants (Sagaspe, Schwartz, & Vuilleumier, 2011). An equal number of stop and go trials were randomly presented during the task, as a 50/50 presentation has been found to yield the best accuracy rates (Donkers & van Boxtel, 2004).

![Stop-Signal Task Illustration](image)

Figure 4. Stop-Signal Task Illustration

During the task, participants were seated alone in a quiet room approximately 70 cm from a 21-inch CRT monitor. E-Prime 2.0 was used to present stimuli and record responses. Participants first received instructions on how to complete the task and were then given two practice trials where they were be presented with 20 images to become acquainted with
responding to stop and go trials. Participants received feedback and were able to ask questions about the task to ensure understanding. During the testing phase of the task, participants completed 720 trials, divided into 12 blocks with a 20s break between each block. Participants received 360 trials displaying healthy images and 360 trials displaying unhealthy images. Fifty-two distinct food images were presented during the task, but images varied in their assignment to either stop or go trial across blocks. Healthy and unhealthy food images were presented randomly across participants.

Although the stop-signal task generates multiple outcome scores for both go trials (i.e., food image presented with no stop-signal) and stop trials (i.e., food image presented with stop-signal), for the purposes of this study, only those scores from stop trials were included in the main analyses, given interest in capturing food-specific inhibition. Therefore, two main scores were included: stop-signal accuracy (SSA) and stop-signal delay (SSD). SSA was defined as the percentage of errors a participant made when presented with the stop-signal (i.e., how many times out of 100 did the participant successfully inhibit response to the food image when presented with the stop-signal). SSD was defined as the amount of time between presentation of the stimulus and presentation of the stop signal. Because the task calibrates and becomes more or less difficult depending on how successful a participant is at withholding responses on the stop trials, the average SSD is a measure of the participant’s ability to inhibit. If a participant has a longer average SSD, this indicates that the participant was successful at inhibiting responses, even when the latency period between food image presentation and stop-signal presentation was longer. In contrast, if a participant has a shorter average SSD, this indicates that the participant had more difficulty inhibiting responses and thus the latency period between food image presentation and stop-signal presentation was shorter.
**Lab-based food task.** Participants were presented with M&M’s and Skittles in a divided bowl (i.e., M&M’s on one side of the bowl and Skittles on the other). Consistent with previous research using lab-based food tasks to assess dietary intake, the bowl was weighed before and after the experiment (Harris, Bargh, et al., 2009), to the nearest .1 gram. The difference in weight of the bowl of candy before and after the experiment was then be calculated to quantify the amount of candy eaten. Because the experimenter also took a handful of candy as a part of the task, the amount of candy that the experimenter took was recorded and subtracted from the final weight given that each piece of candy weighed approximately 1 gram.

**Analyses**

Prior to hypothesis testing, all measures were evaluated for psychometric properties. Descriptive statistics for key variables and demographics were assessed and bivariate correlations for these variables were calculated to assess for relationships between variables. For all analyses, demographic variables (e.g., age) and BMI were utilized as covariates if correlations between those variables and the dependent variables were .4 or greater. Independent t-tests and chi-square comparisons were conducted to assess for group differences in demographic characteristics by high or low disordered eating concerns and by absence or presence of binge eating episodes.

For hypotheses testing, repeated measures analyses of variance (ANOVAs) were used to assess the differential effects of watching food and non-food commercials. For each ANOVA, commercial type (food or non-food commercials) was entered in as the within-subjects factor to assess its impact on each of the dependent variables: (1) general inhibition, measured by the D-KEFS CWIT inhibition score, (2) food-specific inhibition, measured by the stop-signal task, and (3) amount of candy eaten during lab-based food task. The following scores on the stop-signal
task were used to measure food-specific inhibition: SSA for healthy food images - the percent of times that participants correctly inhibited response to a healthy food image when presented with the stop signal, SSA for unhealthy food images - the percent of times that participants correctly inhibited response to an unhealthy food image when presented with the stop signal, and SSD – the amount of time between presentation of the stimulus and presentation of the stop signal across both healthy and unhealthy food images. To assess for moderation, both classifications of disordered eating (i.e., high or low EDE-Q global score and binge or no binge eating) were entered in as between-subjects factors.

**Results**

Overall, participants had a mean BMI of 23.50 ($SD = 1.05$). Approximately nine percent of participants were classified as underweight, 63.6% as normal weight, 18.2% as overweight and 9.1% as having obesity. The majority of participants identified as White/Caucasian (52.3%) and the next largest group identified as Asian (20.5%). Sixty-one percent of participants were first year college students. Independent t-tests and chi-square comparisons revealed that there were no differences in demographics or BMI by either classification of disordered eating (e.g., high versus low EDE-Q global score; endorsement or no endorsement of binge eating episodes) (see Table 5).
Table 5. Participant Characteristics by Disordered Eating Concerns (n=44)

<table>
<thead>
<tr>
<th></th>
<th>High EDE-Q (n=25)</th>
<th>Low EDE-Q (n=19)</th>
<th>Binge (n=26)</th>
<th>No Binge (n=18)</th>
<th>Total (n=44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, n (SD)</td>
<td>18.96 (1.17)</td>
<td>18.74 (0.87)</td>
<td>19.0 (1.10)</td>
<td>18.67 (0.97)</td>
<td>18.86 (1.05)</td>
</tr>
<tr>
<td>BMI, n (SD)</td>
<td>25.76 (6.74)</td>
<td>20.52 (3.08)</td>
<td>24.78 (6.96)</td>
<td>21.65 (3.78)</td>
<td>25.50 (6.02)</td>
</tr>
<tr>
<td>Race, n (%)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>White</td>
<td>14 (56)</td>
<td>9 (47)</td>
<td>14 (54)</td>
<td>9 (50)</td>
<td>231 (60)</td>
</tr>
<tr>
<td>Asian</td>
<td>5 (20)</td>
<td>9 (47)</td>
<td>7 (27)</td>
<td>7 (39)</td>
<td>85 (22)</td>
</tr>
<tr>
<td>Black</td>
<td>1 (4)</td>
<td>0 (0)</td>
<td>1 (4)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>5 (20)</td>
<td>1 (5)</td>
<td>4 (15)</td>
<td>2 (11)</td>
<td>69 (18)</td>
</tr>
<tr>
<td>Ethnicity, n (%)</td>
<td></td>
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<tr>
<td>Hispanic</td>
<td>4 (16)</td>
<td>2 (10)</td>
<td>2 (8)</td>
<td>4 (22)</td>
<td>46 (12)</td>
</tr>
<tr>
<td>Non-Hispanic</td>
<td>21 (84)</td>
<td>17 (90)</td>
<td>24 (92)</td>
<td>14 (78)</td>
<td>339 (88)</td>
</tr>
<tr>
<td>Year in School, n (%)</td>
<td></td>
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<tr>
<td>First</td>
<td>14 (56)</td>
<td>13 (68)</td>
<td>15 (58)</td>
<td>12 (67)</td>
<td>27 (61)</td>
</tr>
<tr>
<td>Second</td>
<td>7 (28)</td>
<td>4 (21)</td>
<td>8 (31)</td>
<td>3 (17)</td>
<td>11 (25)</td>
</tr>
<tr>
<td>Third</td>
<td>3 (12)</td>
<td>1 (5)</td>
<td>2 (8)</td>
<td>2 (11)</td>
<td>4 (9)</td>
</tr>
<tr>
<td>Fourth</td>
<td>1 (4)</td>
<td>1 (5)</td>
<td>1 (4)</td>
<td>1 (6)</td>
<td>2 (5)</td>
</tr>
<tr>
<td>EDE-Q Global, n (SD)</td>
<td>3.28 (0.76)</td>
<td>0.49 (1.15)*</td>
<td>2.65 (1.65)</td>
<td>1.25 (1.39)</td>
<td>2.08 (1.68)</td>
</tr>
<tr>
<td>EDE-Q EC, n (SD)</td>
<td>2.06 (1.30)</td>
<td>0.29 (0.96)*</td>
<td>1.75 (1.61)</td>
<td>0.64 (0.87)</td>
<td>1.30 (1.46)</td>
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<tr>
<td>EDE-Q SC, n (SD)</td>
<td>4.19 (0.98)</td>
<td>0.72 (1.32)*</td>
<td>3.27 (1.95)</td>
<td>1.81 (1.98)</td>
<td>2.66 (2.07)</td>
</tr>
<tr>
<td>EDE-Q WC, n (SD)</td>
<td>3.88 (0.97)</td>
<td>0.48 (1.07)*</td>
<td>2.91 (1.90)</td>
<td>1.64 (1.90)</td>
<td>2.38 (1.98)</td>
</tr>
<tr>
<td>EDE-Q Restraint, n (SD)</td>
<td>3.00 (1.24)</td>
<td>0.46 (1.33)*</td>
<td>2.58 (1.71)</td>
<td>0.92 (1.44)*</td>
<td>1.90 (1.79)</td>
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<tr>
<td>EDE-Q Binge, n (SD)</td>
<td>3.84 (4.81)</td>
<td>1.63 (2.41)</td>
<td>4.88 (4.28)</td>
<td>0.00 (0.00)*</td>
<td>2.89 (4.07)</td>
</tr>
</tbody>
</table>

*One-way analysis of variance (ANOVA) significant at p <.006, reflecting Bonferroni adjustment for multiple comparisons.

EDE-Q = Eating Disorder Examination-Questionnaire; EC – Eating Concerns, SC – Shape Concerns; EDE-Q Binge – Item 15 of EDE-Q assessing binge eating.
With regards to disordered eating, participants had an average EDE-Q global score of 2.08 ($SD = 1.68$). Figure 5 shows the distribution of EDE-Q global scores across the sample, reflecting the fact that only participants at the high and low end of the spectrum of EDE-Q global score were recruited for this study. T-tests revealed that individuals who endorsed binge eating also had significantly higher EDE-Q global scores than those who did not (see Table 5). Although there was no significant difference in the average amount of binge eating episodes endorsed by those with high EDE-Q global scores versus those with low EDE-Q global scores (see Table 5), 42% of individuals with a low EDE-Q global score reported binge eating at least one time whereas 72% of individuals with a high EDE-Q global score reported binge eating at least once. Participants completed the EDE-Q an average of 51 days ($SD = 42$ days) prior to coming into the lab to complete the rest of the study due to the time required to invite and schedule study visits.

![Figure 5. Sample Distribution of EDE-Q Global Scores](image)
With regards to the outcome measures, for the D-KEFS CWIT inhibition scale, a measure of general inhibition, participants had an average scaled score of 12 ($SD = 1$), falling within the average range (Delis et al., 2001). On the stop-signal task, participants were 83% accurate ($SD = 11.74\%$) on stop signal trials for both healthy and unhealthy food images, and the average delay between presentation of the stimulus and presentation of the stop-signal was 489.77 milliseconds ($SD = 22.36$). Overall, for go-trials, an ANOVA revealed that participants had slower reaction times $F(1,41) = 16.77, p < .001$, and lower accuracy, $F(1,41) = 15.993, p < .001$, when they saw unhealthy food images as opposed to when they saw healthy food images. Finally, participants took an average of 25.05 grams of candy during the task ($SD = 16.84$). Only two participants did not take any candy during the task. Because neither demographic characteristics nor BMI were significantly associated with either measures of inhibition or food consumption above $r = .4$, they were not included in subsequent models as covariates. Means, standard deviations, and correlations are presented in Table 6.
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<tbody>
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<td>1.Age</td>
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<tr>
<td>2.BMI</td>
<td>-.29</td>
<td>.44*</td>
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<td>3.EDE-Q</td>
<td>.16</td>
<td>.50**</td>
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<td>4.SSA-U Food</td>
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<td>.01</td>
<td>-.03</td>
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<td>5. SSA-H Food</td>
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<td>.08</td>
<td>.03</td>
<td>.91**</td>
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<td>6.SSA-U NF</td>
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<td>.02</td>
<td>-.11</td>
<td>.81**</td>
<td>.77**</td>
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<td>7. SSA-H NF</td>
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<td>.12</td>
<td>-.02</td>
<td>.75**</td>
<td>.82**</td>
<td>.89**</td>
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<td>8.SSD Food</td>
<td>-.37*</td>
<td>-.01</td>
<td>-.03</td>
<td>.74**</td>
<td>.77**</td>
<td>.64**</td>
<td>.68**</td>
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<tr>
<td>9. SSD NF</td>
<td>-.37*</td>
<td>.14</td>
<td>.08</td>
<td>.72**</td>
<td>.64**</td>
<td>.82**</td>
<td>.71**</td>
<td>.67**</td>
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<td>10.D-KEFS Food</td>
<td>.16</td>
<td>.38*</td>
<td>.36*</td>
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<td>.08</td>
<td>.03</td>
<td>.09</td>
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*p<.05; **p<.004 (Bonferroni corrected significance level adjusted for multiple comparisons)

EDE-Q Global – Eating Disorder Examination Questionnaire Global Score; SSA-U Food – Stop signal accuracy for stop trials containing unhealthy foods, when food commercials viewed (out of 1.00); SSA-H Food – Stop signal accuracy for stop trials containing healthy foods, when food commercials viewed (out of 1.00); SSA-U NF – Stop signal accuracy for stop trials containing unhealthy food, when non-food commercials viewed (out of 1.00); SSA-H NF – Stop signal accuracy for stop trials containing healthy food, when non-food commercials viewed (out of 1.00); SSD Food – Stop signal delay when food commercials viewed (in milliseconds); SSD NF – Stop signal delay when non-food commercials viewed (in milliseconds); D-KEFS Food – D-KEFS Inhibition scaled score when food commercials viewed; D-KEFS NF – D-KEFS inhibition scaled score when non-food commercials viewed; Candy Food – Candy consumed when food commercials viewed (in grams); Candy NF – Candy consumed when non-food commercials viewed (in grams).
Television Commercials and General Inhibition

To address the first aim, the impact of food and non-food commercials on general inhibition (i.e., performance on the D-KEFS CWIT) was tested. A repeated measures ANOVA indicated no significant main effect of commercial type on performance on the D-KEFS CWIT inhibition measure \( (p = .801; \eta^2 = .002) \). Additionally, to address Aim Four, the moderating effects of both classifications of disordered eating were assessed. Results of the ANOVA indicated that the effect of food and non-food commercials on general inhibition did not differ based on whether participants had high or low EDE-Q global scores \( (p > .05, \eta^2 = .006) \), nor did they differ based on whether participants endorsed or did not endorse binge eating \( (p > .05; \eta^2 = .02) \). However, there was a main effect of EDE-Q global score on inhibition, such that individuals with high EDE-Q global scores had higher D-KEFS CWIT inhibition scale scores \( (M = 13) \) than those with low EDE-Q global scores \( (M = 12) \), regardless of commercial type, \( F(1,40) = 7.88, \ p = .008, \eta^2 = .17 \). There were no main effects of binge eating on general inhibition \( (p = .392; \eta^2 = .02) \).

Television Commercials and Food-Specific Inhibition

To address the second aim, the impact of food and non-food commercials on food-specific inhibition (i.e., performance on the stop-signal task, as measured by SSA and SSD) was tested. ANOVAs revealed that there was no significant main effect of commercial type on SSA (i.e., the percent of time that a participant correctly inhibited response when presented with the stop-signal) when participants were presented with either healthy food images or with unhealthy food images \( (p = .786; \eta^2 = .002) \). Additionally, there was also no significant main effect of commercial type on SSD (i.e., the amount of time between stimulus presentation and stop signal...
presentation across healthy and unhealthy food images), an indicator of overall performance on the task \( (p = .760; \eta^2 = .002) \).

To address Aim Four, the moderating effects of both classifications of disordered eating were also assessed. The ANOVAs again revealed that the effect of food and non-food commercials on food-specific inhibition (i.e., SSA or SSD) did not differ based on whether participants had high or low EDE-Q global scores (SSA: \( p = .853; \eta^2 = .001 \); SSD: \( p = .762; \eta^2 = .002 \)), nor did it differ based on whether participants endorsed or did not endorse binge eating, for either SSA \( (p = .313; \eta^2 = .03) \) or SSD \( (p = .543; \eta^2 = .009) \). There were also no significant main effects of either classification of disordered eating (using EDE-Q global score or binge eating) on SSA (EDE-Q global: \( p = .138; \eta^2 = .05 \); binge eating: \( p = .081; \eta^2 = .07 \)) or SSD (EDE-Q global: \( p = .255; \eta^2 = .03 \); binge eating: \( p = .505; \eta^2 = .01 \)).

**Television Commercials and Lab-Based Food Task**

To address the third aim, the impact of food and non-food commercials on a lab-based food task was tested. Similar to the previous two aims, a final repeated measures ANOVA revealed no significant main effect of commercial type on the amount of candy eaten during the lab-based food task \( (p = .447; \eta^2 = .02) \). The ANOVA also revealed that high or low EDE-Q global scores did not moderate the relation between commercial type and amount of candy eaten \( (p = .198; \eta^2 = .04) \), addressing Aim Four. However, there was a significant interaction between commercial type and endorsement of binge eating, \( F(1, 38) = 8.75, p = .005, \eta^2 = .19 \) (see Figure 6). Post-hoc t-tests revealed that participants who endorsed binge eating ate more candy after watching food commercials \( (M = 34.06 \text{ grams}) \) than those who did not endorse binge eating \( (M = 18.67 \text{ grams}) \), \( t(40) = -2.53, p = .015 \), but there was no significant difference in the amount of candy eaten by those who endorsed binge eating and those who did not endorse binge eating.
after viewing non-food commercials ($p = .671$). There were no main effects of either classification of disordered eating (using EDE-Q global score or binge eating) on food-specific inhibition (EDE-Q global: $p = .199$; $\eta^2 = .04$; binge eating: $p = .438$; $\eta^2 = .02$).

![Figure 6. Commercial Type by Binge Eating Interaction](image)

**Discussion**

Food companies spend over a billion dollars in marketing unhealthy food products to youth. Although a number of studies have found that unhealthy food marketing is associated with increased dietary intake in children, few studies have focused on how such marketing may impact late adolescents and emerging adults. Additionally, there is a lack of research investigating the mechanisms underlying the relation between unhealthy food marketing and increased dietary intake. Specifically, little is known about the association between food marketing and inhibition, including whether inhibition may explain why some individuals may be more vulnerable to unhealthy food marketing than others. The current study sought to examine the impact of unhealthy food marketing on inhibition in a late adolescent/emerging
adult sample. It also investigated the impact of unhealthy food marketing on actual intake in a lab-based food task. Finally, the current study also evaluated whether the following classifications of disordered eating may act as moderators: (1) high or low transdiagnostic characteristics of disordered eating (measured by EDE-Q global score), (2) endorsement or no endorsement of binge eating. Results indicated that there was no difference between unhealthy food commercials and non-food commercials on either general inhibition (using non-food-specific cues) or food-specific inhibition (using food-specific cues). In addition, these effects did not vary based on whether individuals had high or low global scores on the EDE-Q or whether they did or did not endorse binge eating. However, regardless of commercial type, individuals with high EDE-Q global scores performed better on a task of general inhibition than those with low EDE-Q global scores. This study also found that although there was no overall effect of commercial type (food or non-food) on actual food intake in the lab, there was a moderating effect of binge eating. Specifically, individuals who endorsed binge eating ate more candy after watching food commercials than those who did not endorse binge eating, but there was no difference in candy consumed between the two groups after watching non-food commercials. However, high or low EDE-Q global score did not moderate the relation between commercial type and food intake in the lab.

This study is the first, to our knowledge, to examine the impact of watching food and non-food commercials on performance on a series of inhibition tasks. The finding that neither general nor food-specific inhibition was impacted by viewing unhealthy food commercials was contrary to our hypotheses. These findings may be an indication that food commercials do not directly impact inhibition in late adolescents/emerging adults but may instead impact other processes, such as motivation or desire for food. However, one other possible explanation for
these findings may lie in the type of non-food commercials that were used in the experiment. All of the commercials were chosen based on the fact that they were commonly advertised on women-focused television channels. Although commercials were separated into “food” and “non-food” categories with the assumption that response to food commercials would require the largest amount of inhibition, 3/5 of the commercials in the “non-food” category were focused on products that claimed to improve appearance, such as makeup (two commercials) and hair products (one commercial). There is evidence to suggest that commercials that focus on appearance may actually be associated with both self-esteem and body image disturbances, especially in young women who may watch such commercials and then compare themselves to a societal ideal (Hesse-Biber, Leavy, Quinn, & Zoino, 2006). Thus, it is possible that when participants watched and then wrote about the non-food commercials in the study and were asked to describe why they should not purchase the products advertised, this might have required as much effort as it did for the food commercials. Therefore, participants may have completed the inhibition tasks feeling as depleted after non-food commercials as they did after food commercials, thus impacting the results.

In addition to the main findings assessing inhibition, the current study also found that neither classification of disordered eating (either by high/low EDE-Q global score or by endorsement/no endorsement of binge eating) moderated the relation between commercial type and performance on the general or food-specific inhibition tasks. Although no studies to our knowledge have evaluated the moderating impact of disordered eating on the relation between food marketing and inhibition, past research suggests that, outside of the context of food marketing, individuals with eating disorders often perform no worse on general measures of inhibition, like the standard Stroop task, than those without eating disorders (Dobson & Dozois,
This is generally consistent with the current study finding that regardless of commercial type, individuals with high EDE-Q global score performed moderately better on the D-KEFS CWIT than those with low EDE-Q global score. However, there is also past evidence to suggest that individuals with eating disorders often perform worse than those without eating disorders on tasks that are related to the eating disorder (such as a modified Stroop task with food or body related words) (Dobson & Dozois, 2004). The results of the current study stand in contrast to these findings, given that there was no main effect of disordered eating (classified either way) on stop-signal results, nor was there any interaction of disordered eating on the relation between commercial type and stop-signal performance.

There are several possible explanations for these findings. First, it is possible that since the current study used a non-clinical sample, the observed differences in food-specific inhibition were not as great as those found in clinical samples. Second, the stop-signal task in the current study only used food images and had no non-food images, whereas past studies of individuals with eating disorders have compared response to food/body-specific stimuli to that of neutral stimuli. Therefore, it is possible that the difference seen when using food/body stimuli versus non-food stimuli does not extend to a task using only unhealthy and healthy food stimuli.

Consistent with the results of the inhibition tasks, the current study also found that there was no impact of commercial type on actual food intake in the lab. This finding is consistent with research by Harris, Bargh, et al. (2009) using a sample of college students similar to the one used in the current study. Harris, Bargh, et al. found that when the sample included both males and females, there was a significant impact of watching unhealthy food commercials on subsequent food intake in the lab. However, analyses of gender differences showed that although male eaters were particularly impacted by unhealthy food commercials, eating up to 1 SD more
food than they did after watching non-food commercials, female eaters ate approximately the same amount of food after watching unhealthy food commercials and non-food commercials, which is consistent with our findings.

Despite the lack of a main effect of commercial type on food intake in the lab, the current study did find that binge eating significantly moderated the relation between commercial type and food intake. Individuals who endorsed binge eating ate more candy after viewing food commercials than those who did not endorse binge eating, but there was no difference between the two groups after watching non-food commercials. Although this might be due to the high levels of dietary restraint seen in binge eaters, individuals with high EDE-Q global scores, who were also higher in dietary restraint than those with low EDE-Q global scores, were not differentially impacted by watching food commercials. This indicates that dietary restraint may not be the only salient factor. Indeed, these findings suggest that, even in non-clinical samples, there may be a distinct difference between individuals who endorse transdiagnostic characteristics of disordered eating (i.e., have a high EDE-Q global score - a combination of restraint, weight concerns, shape concerns, and eating concerns) and those who report specific and quantifiable disordered eating behaviors, such as binge eating. Although, as expected, a majority of individuals with a high-EDE-Q global score reported at least one episode of binge eating, surprisingly over 40% of individuals with a low EDE-Q global score endorsed at least one binge eating episode. This is likely because items assessing frequency of binge eating on the EDE-Q are not used to calculate the EDE-Q global score. Therefore, one salient difference between the high EDE-Q global score group and the binge eating group is that although individuals in both groups endorsed high levels of dietary restraint, individuals in the binge eating group also endorsed instances that represented a failure to exercise restraint.
Strengths and Limitations

This study has several strengths, including a multi-method assessment of inhibition utilizing a variety of tasks. This study also pretested all commercials to match them on levels of valence and arousal to ensure that any effects seen in the experiment was not simply a result of affect manipulation. Additionally, the use of multiple classifications of disordered eating is also a strength, allowing for examination of both transdiagnostic characteristics of disordered eating as well as more specific eating behaviors (i.e., binge eating). Another strength is the within-subjects design of this study, which minimized variability between groups and allowed for more precise accounting for individual differences. Limitations of the study include small sample size, which decreased the statistical power to detect significant effects, specifically the within-subjects and between-subject variable interactions. The homogeneous sample of the study is also a limitation, as the study included mostly White participants. Given that this study also only included women, it is difficult to generalize the findings to men and ethnic minorities, for whom disordered eating may look different than it does for White women (Rodgers, Berry, & Franko, 2018). Additionally, both the amount of time as well as the variability in the time between the assessment of disordered eating and participation in the experimental sessions is also a limitation. Participants completed the study from two weeks to three months after they completed the EDE-Q. Although research demonstrates good test-retest reliability of the EDE-Q global score up to almost one year, reliability of specific disordered eating behaviors, like binge eating, is lower (Mond, Hay, Rodgers, Owen, & Beumont, 2004), thus it is possible that specific levels of disordered eating may have changed between initial assessment and experimental session. Finally, although this study examined individuals with and without binge eating, we
were not able to consider whether other types of eating behaviors, such as fasting or vomiting, may have an effect due to the low prevalence rates in the sample.

Future studies should examine the impact of unhealthy food marketing on inhibition using larger, more diverse samples so that findings may be more easily generalized. Since the current study did not find evidence that unhealthy food marketing impacts inhibition, future research should investigate whether other factors, such as motivation or desire, may drive the tendency for some individuals to eat more food after watching unhealthy food commercials. Research is also needed to assess whether advertisements focusing on physical appearance have similar negative effects on women as those that focus on unhealthy food. Additionally, given the recent emphasis on identifying eating disorders in men, research should evaluate which components of food marketing may differentially impact men. Future studies should also investigate the impact of advertisements outside of television commercials, such as those on social media. Finally, given that this study focused on a non-clinical population, future studies should also examine the impact of food marketing in clinical populations where there are more individuals with a variety of disordered eating behaviors, not just binge eating.

Conclusion

This mixed-methods study augments the current literature by providing evidence that individuals who endorse binge eating may be more impacted by unhealthy food marketing than those who do not endorse binge eating. Findings from this study also support the argument that childhood is not the only important time period to consider when evaluating the impact of food marketing, and in turn, that late adolescence and emerging adulthood may also be a time of risk. Understanding the impact of unhealthy food marketing across youth and young adulthood, as
well as the mechanisms underlying that relation, is important for designing effective public health interventions to reduce the negative effects of food marketing.
CHAPTER FIVE

DISCUSSION

The current set of studies assessed the relation between EF and dietary intake, and the environmental factors that influence the relation, across youth and emerging adulthood. Study 1, “Executive Function and Dietary Intake in Children: A Systematic Review of the Literature,” presented a comprehensive review of the relation between EF and dietary intake during youth through a developmentally sensitive lens. Findings from this review indicated that the association between EF and dietary intake is equivocal. The review found some evidence for a bi-directional relation between EF and dietary intake, but the lack of longitudinal studies made interpretation of these findings difficult. Results also indicated that there is a disparity between the amounts of research investigating the way that different components of EF may be associated with dietary intake. Specifically, the majority of cross-sectional studies identified in the review focused on the relation between inhibition and dietary intake, but fewer studies investigated working memory or cognitive flexibility. Several studies identified in the review also evaluated the impact of interventions to either (1) alter dietary intake to improve EF or (2) alter EF in order to improve dietary intake. Results from these studies indicated that interventions aimed at altering dietary intake in order to improve EF are largely ineffective, and in turn, that there are very few studies investigating the impact of training EF in order to improve dietary intake in youth. With regards to developmental considerations, most studies in the review focused on
elementary age children, therefore less is known about how EF and dietary intake may function together in preschool or adolescent youth. Overall, the findings from this review indicated that although there appears to be some relation between EF and dietary intake in youth, there are both individual and environmental factors that may impact that relation in this population.

Some of the factors that may influence the relation between EF and dietary intake in youth are illustrated by the second study in this series, “The Heat is on: A Mixed-Method Examination of Eating Behavior and Executive Functions among Low Income Minority Girls during Summertime.” Study 2 investigated the association between EF and dietary intake in a sample of low-income, early adolescent girls during the summertime. The two main findings of this study indicated that both environmental and individual factors may influence the relation between inhibition and dietary intake. First, results indicated that during the summertime, a period of disruption in the structured schedule that is often required of children during the school year, there was an overall association between higher caloric intake and higher sugar sweetened beverage intake and worse inhibition. Second, this study also found that during this time period, eating late at night was associated with poorer EF. Specifically, girls who ate more than 20% of their meals after 8pm evidenced worse inhibition skills than those who did not. Taken together, these results indicated that during periods where adolescents have less environmental structure, individual eating patterns may be associated with poorer EF. Findings from this study also revealed that only inhibition was significantly related to dietary intake, whereas working memory and cognitive flexibility were not, which is consistent with the results of Study 1.

The third study in this series, “The Impact of Viewing and Responding to Unhealthy Food Marketing on Inhibition in Adolescents and Emerging Adults: Disordered Eating as a Moderator,” also illustrated the interplay of environmental and individual factors on the relation
between EF and dietary intake. The study examined the impact of unhealthy food marketing on inhibition and investigated the moderating influence of disordered eating in a sample of late adolescent/emerging adult women. In order to capture different facets of disordered eating, Study 3 categorized the sample in two different ways: (1) into high and low transdiagnostic symptoms of disordered eating, and (2) more specifically into endorsement or no endorsement of binge eating. The study also measured two facets of inhibition, including general inhibition and food-specific inhibition, and showed two types of commercials, food commercials and non-food commercials. The results of Study 3 indicated no effect of the type of commercial viewed on either general inhibition or food-specific inhibition assessed in a lab setting, and no interaction of disordered eating, classified in either of the two ways. In addition to this, when individuals were given the opportunity to consume actual food in the lab, the type of commercial viewed (food or non-food) made no overall difference in the amount of food consumed, but there was an interaction between food consumption and binge eating. Specifically, individuals who endorsed binge eating ate more candy after watching food commercials than those who did not endorse binge eating, but after viewing non-food commercials, candy consumption was not different between the two groups. However, this moderation effect was not significant when the sample was re-categorized into high or low transdiagnostic characteristics of binge eating.

Overall, the findings from this series of studies are generally consistent with existing literature. First, all three studies highlighted the cross-sectional relation between inhibition and dietary intake. Past research has also found that inhibition appears to be the component of EF that is most widely studied and is most often associated with dietary intake cross-sectionally (Dohle et al., 2017). However, Study 1 extended this finding by suggesting that the lack of literature on the relation between working memory or cognitive flexibility/task switching and
dietary intake makes it difficult to ascertain whether there is a stronger relation between inhibition and dietary intake, or whether the other two components of EF are simply understudied in youth. In addition to this, all three studies indicated that both environmental and individual factors likely play a role in dietary intake, supporting existing models of obesity development suggesting that obesity is influenced by a child’s ecosystem, which is composed of individual, environmental, and societal factors (Davison & Birch, 2001). Specifically, the findings from Study 2 were consistent with previous literature that speaks to the negative impact that one environmental factor, summertime, may have on youth (Franckle, Adler, & Davison, 2014; Mahoney, 2011). This study illustrated that children may be vulnerable to overeating during the summertime, and that this vulnerability may be particularly salient for children with less healthy eating patterns, such as eating late at night. Study 3 also emphasized the interplay between environmental and individual factors by illustrating the impact of food marketing on inhibition, especially for individuals with disordered eating. These results are also consistent with previous literature demonstrating that exposure to food marketing is associated with increased calorie consumption (Harris, Bargh, et al., 2009).

In addition to supporting existing literature, the three studies in this series also extend the findings from previous studies. For example, Study 1 extended the work of previous reviews by evaluating EF and dietary intake from a bi-directional perspective. It combined findings from related, but distinct areas of psychology by evaluating both how dietary choices may influence EF developmentally, and also how individual differences in EF may impact what and how much a child eats. This review also discussed both cross-sectional findings as well as interventional findings to paint a more comprehensive picture of how alterations in EF or dietary intake may impact the other. Finally, it is the first systematic review, to our knowledge, to consider
associations between EF and dietary intake from a developmental perspective, and to evaluate the existing literature by age group to determine how findings may differ by age. Studies 2 and 3 also extended the existing literature by investigating how individual factors (i.e., disordered eating behaviors) may influence well-established environmental correlates of dietary intake. By evaluating such factors in late adolescents/emerging adults, Study 3 also emphasized the need to consider this age range when discussing dietary intake and the development of obesity, as this age range represents a time of increased independence over food choices.

The current series of studies also extend previous literature by highlighting the role of disordered eating in the relation between EF and dietary intake. Specifically, both Study 2 and Study 3 lent support to the idea that individuals with disordered eating may be more impacted by environmental influences on dietary intake and EF than those without disordered eating. As previously discussed, Study 3’s finding that individuals with binge eating tended to eat more following food commercials than those without binge eating, and that there was no difference between the groups following non-food commercials, may be due to the increased levels of restraint seen in individuals with binge eating. This is consistent with Fairburn’s transdiagnostic theory of disordered eating, which states that binge eating often comes as a result of lapses in the attempt to restrict dietary intake (Fairburn et al., 2003). However, despite the increased levels of restraint seen in the high disordered eating group, it is notable that there was no interaction between high or low EDE-Q global score and commercial type. This may be for a number of reasons. First, global disordered eating concerns capture individuals with high levels of dietary restraint who are both successful at dieting and not successful at dieting. Therefore, it is possible that the high variability within the “high disordered eating” group may have impacted the
findings. Second, it is also possible that binge eating specifically may be a risk factor for eating more after exposure to food marketing, where other disordered eating behaviors are not.

Similar to Study 3, Study 2 also highlighted the role of disordered eating patterns in the relation between EF and dietary intake. In Study 2, individuals with night eating had worse inhibition than those without night eating, and individuals with worse inhibition ate more calories and drank more SSBs than those with better inhibition. However, no direct link was found between night eating and increased dietary intake. This stands in contrast to Study 3, which found a direct link between disordered eating and dietary intake, but no direct link between disordered eating and EF. These differences in findings may highlight the distinction between binge eating and night eating. Although participants in both studies were drawn from a non-clinical population, binge eating and night eating, even in subclinical form, may represent two very different patterns of dietary intake. Furthermore, although much less is known about night eating than about binge eating, it is possible that night eating may be associated with less overall impairment than binge eating, even when binge eating is measured in a non-clinical sample.

One other distinction that may explain differences in the results of Study 2 and Study 3 is the age of participants included in both studies. Results from Study 1 indicated that the majority of studies examining cross-sectional associations between dietary intake and EF focus on elementary age youth. Therefore, both Study 2 and Study 3 extend the current literature by including older youth. Study 2 focused on early adolescence, a time of rapid development of EF (P. Anderson, 2002), while Study 3 assessed older adolescents and emerging adults, a group often left out of the discussion on food marketing. However, these age differences may have also impacted the disparate findings between the two studies with regards to the impact of disordered
eating on dietary intake. It is possible that although youth in Study 2 who engaged in night eating had worse inhibition than those who did not, their daily dietary intake was still largely controlled by their parents, who took responsibility for choosing and preparing meals. In contrast, the participants in Study 3 were largely living on campus, away from parents, and were responsible for their own dietary intake. Additionally, Study 3 also assessed dietary intake in the lab, while Study 2 assessed dietary intake in real life, and it is possible that if the night eaters in Study 2 had been given the chance to consume food in a lab-based setting, away from their parents, results would have been similar to those in Study 3.

**Strengths and Limitations**

The current series of studies have several strengths, including a comprehensive systematic review evaluating the bi-directionality of the relation between EF and dietary intake across development (Study 1), demographic diversity between study participants (Study 2 and Study 3), and a discussion by all studies of the environmental and individual aspects that may impact EF and dietary intake. This series of studies also investigated the full range of child development, from preschool to emerging adulthood through the use of cross-sectional and longitudinal studies. Finally, both Study 2 and Study 3 utilized well-validated measures of EF to measure inhibition (Studies 2 and 3), working memory (Study 2), and cognitive flexibility (Study 2). Some limitations of the current studies include the small sample size of Studies 2 and 3 which may have impacted statistical power. Additionally, both studies included self-report measures to assess for dietary intake (Study 2) and disordered eating (Study 3), and research suggests that individuals often underreport their dietary intake (McPherson et al., 2000) and overreport disordered eating concerns (Berg et al., 2011), which may have impacted the findings. Finally,
both Study 2 and Study 3 only included female participants, therefore it is difficult to extend the findings to individuals of other genders.

**Future Directions**

All three studies demonstrate the need for more longitudinal research investigating the relation between EF and dietary intake in youth. Results from the systematic review indicate that very few longitudinal studies have examined EF and dietary intake outside of an intervention, and the few existing longitudinal studies did not distinguish between the age of participants or the domain of EF. Furthermore, the findings from cross-sectional studies do not always match the findings from existing longitudinal studies, especially in the domain of inhibition where there is little evidence of a longitudinal relation with dietary intake. Additionally, although there is some evidence of a bidirectional relation between working memory and dietary intake, very few studies have investigated either working memory or cognitive flexibility longitudinally and more research is needed to understand how they may relate to dietary intake. With regard to longitudinal interventions, despite little support for the effectiveness of interventions to alter dietary intake in order to improve EF, more studies are needed to examine the inverse relation – whether altering EF may improve dietary intake. Additionally, more follow-up studies are also needed to examine long-term effects of interventions.

In addition to the need for more longitudinal studies, more research is needed to understand the relation between EF and dietary intake in men, especially those with disordered eating. Given that many studies that evaluate disordered eating focus on women (Ricciardelli & McCabe, 2004), including the two studies in this series, it is important to use measures that adequately capture male disordered eating symptoms in order to understand the role that these symptoms may play in influencing EF and/or dietary intake. Furthermore, for both men and
women, future studies should investigate the mechanisms behind existing findings. Specifically, although research demonstrates that individuals with higher levels of dietary restraint tend to eat more in response to television commercials, little is known about why this occurs. Additionally, across genders, future research with larger samples is needed to understand the role of inhibition in individuals with both clinical and subclinical levels of disordered eating, as well as how inhibition may interact with environmental factors, such as food marketing, in these populations. Finally, outside of the realm of disordered eating, in general, more research is needed to investigate other individual and environmental factors that may impact the relation between EF and dietary intake.

**Conclusion**

In sum, findings from the current series of studies indicate that the relation between EF and dietary intake in youth is complex, and that both environmental and individual factors likely influence that relation. In addition to indicating the need for more research investigating EF and dietary intake in this population, the current findings also suggest that it is important to identify individuals who may be more responsive to the current food environment, such as individuals with disordered eating, in order to design prevention programs to help them safeguard against unhealthy dietary intake and ultimately against obesity.
CHAPTER SIX
SUPPLEMENT – VALENCE AND AROUSAL: WHY ASSESSING AFFECTIVE RESPONSE MATTERS FOR ADVERTISING RESEARCH

Advertising is a billion-dollar industry (Federal Trade Commission [FTC], 2012), with the potential to influence and alter behavior. Research suggests that exposure to a particular brand increases both liking of and preference for that brand (McClure et al., 2004; Stasi et al., 2018). The effects of advertising on behavior have been studied in children (Robinson et al., 2007), adolescents (Saffer & Dave, 2006), and adults (Harris, Bargh, et al., 2009), with a consistent message that advertising can alter attitudes (Gresham & Shrimp, 1985) and purchasing behaviors (Vakratsas & Ambler, 1999). However, the majority of advertising research has failed to control for factors in advertisements that are known to influence the way humans process stimuli (Dolcos, LaBar, & Cabeza, 2004; Lithari et al., 2010; Rozenkrants, Olofsson, & Polich, 2008) and in turn, influence behavior (Sundar & Kalyanaraman, 2004). The present study illustrates the importance of accounting for valence and arousal in advertising effects research, and offers a novel and replicable method for efficiently conducting valence and arousal assessment of television commercials.

Advertising has been defined as “a paid, mediated form of communication from an identifiable source, designed to persuade the receiver to take some action now or in the future” (Richards & Curan, 2002, p. 74). Early research on advertising was often concerned with the persuasiveness of an ad based on its ability to elicit attitude change and was measured by
collecting product ratings both before and after presenting a series of ads, and then using the change in rating scores as a metric of persuasiveness (Krugman, 1965). However, given the long-standing criticism that advertisements may impact behavior without producing explicit attitude change (Krugman, 1965), researchers have sought to find other methods of examining advertising effectiveness. Recently, the field of neuromarketing has emerged as a method of examining advertising effectiveness from a neuroscientific perspective (Boricean, 2009), and the use of neuroscience methods in advertising research continues to increase rapidly. In the first neuromarketing study of its kind, McClure and colleagues (2004) used functional magnetic resonance imaging (fMRI) to demonstrate that when individuals drink from a branded cup, their judgements about the beverage are associated with activation in hippocampus, dorsolateral prefrontal cortex, and midbrain, whereas when they drink from a non-branded cup, there is activation in ventromedial prefrontal cortex. The authors concluded that a network of cortical and subcortical brain regions work together to integrate sensory (e.g., taste) and cultural (e.g., product branding) information to influence brand preferences (McClure et al., 2004).

More recently, psychophysiological methods (e.g., skin conductance and heart rate to measure arousal, eye tracking to measure visual attention, electroencephalography; EEG and fMRI to measure neural function), have become an important addition to traditional advertising research (see Stasi et al., 2018 for a review of neuromarketing research). Such research often presents individuals with commercial clips and then assesses a subsequent behavioral, physiological, or psychological response to those commercials. This methodology is especially apparent in the area of food advertising research, a subfield that has been at the forefront of incorporating neuroscience into measurement (Stasi et al., 2018). However, although much emphasis has been placed on developing innovative methods to measure individual response to
advertisements, less attention has been given how the affective properties of advertisements may influence psychophysiological responses, resulting in including unintended confounds in past neuromarketing research.

**The Circumplex Model of Emotion: Valence and Arousal**

The circumplex model of emotion theorizes that affective response to stimuli is characterized by two distinct dimensional domains: (1) valence (i.e., the range of pleasant to unpleasant emotions evoked by a stimulus) and (2) arousal (i.e., feelings that range from excited to calm) (Barrett & Russell, 1999; Russell, 1980), and discrete patterns of regional brain activity and physiological response may be associated with each domain (Heller, 1990; 1993). Valence and arousal are conceptualized as orthogonal constructs (Feldman, 1995), such that a stimulus may be high in one but low in the other or similar in both. Valence and arousal influence attention (Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004; Olofsson & Polich, 2007; Rozenkrats & Polich, 2009) such that processing valenced information often requires increased attentional resources (Müller, Andersen, & Keil, 2008). Long term memory is also impacted by affective response, and people remember highly arousing images better, even one year later, and have faster reactions to and increased encoding of these images (Bradley, Greenwald, Petry, & Lang, 1992).

**Valence and Arousal in Advertising**

There is a large body of research examining the impact of emotion on advertising effectiveness which indicates that both valence and arousal influence the way a message is processed (Shapiro & MacInnis, 2013). Early advertising research circa 1980-1990 typically conceptualized emotion as a singular construct (valence) and thus only evaluated the valence of a particular ad. As a result, findings from this era of research confounded valence and arousal:
negative messages were remembered more frequently than positive messages, yet highly emotional messages, whether positive or negative, were remembered more than less emotional messages (Lang, Dhillon, & Dong, 1995). However, when conceptualized from a multidimensional perspective considering valence and arousal as distinct constructs, Lang and colleagues found that after accounting for levels of valence, highly arousing advertisements were remembered more easily than less arousing advertisements. Similarly, when accounting for levels of arousal, positively valenced messages were remembered more easily than negatively valent messages. In addition to impacting memory for advertising messages, valence and arousal also impact attitudes toward an ad (Eckler & Bolls, 2011) and opinions about the usefulness of an ad (Lee, Xiong, & Hu, 2012).

Despite findings that illustrate the importance of assessing valence and arousal in advertising research, measurement of these affective domains has frequently been neglected. This oversight is particularly salient in the food advertising literature, where many studies have sought to examine the impact of unhealthy food advertising on subsequent behaviors, such as food consumption or neurobiological response (e.g., Stasi et al., 2018), but have largely ignored the role of valence and arousal associated with food stimuli, images, and commercials. This is problematic given evidence that higher levels of valence and arousal influence food intake (Macht, 2008), require more attentional resources to process (Müller et al., 2008), and increase the likelihood of consuming a particular product (Meiselman, 2015). Although the affective response evoked by an advertisement has typically not been viewed by advertisement researchers as central to key research questions, we theorize that valence and arousal will typically influence observed behavioral responses in this area of research (see Figure 7). Furthermore, without accounting for affective valence and arousal, it is impossible to ascertain whether an
advertisement’s impact on subsequent behavior is due to the actual product that it is advertising (e.g., food) or the evoked affective response.

Figure 7. Contribution of Valence and Arousal in Observable Responses to Advertisements

Given these concerns, the present study offers a replicable method for assessing affective valence and arousal responses evoked by television advertisements. This study also seeks to contextualize prior findings from food advertising research by evaluating whether food advertisements differ in valence and arousal from non-food advertisements. Additionally, the present study also investigates the valence and arousal of advertisements for similar products to examine whether affective response may be consistent across product categories.

Method

Participants

Participants in the present study were females between the ages of 18-25 ($M = 22.95$ years, $SD = 1.71$) who were living in the United States at the time of the study. This demographic was chosen because the data from this study were used to account for levels of
valence and arousal in a larger study of food advertising in this population. A total of $N = 354$ participants met demographic criteria. Of those, 29 participants did not have complete data and were thus excluded from the analyses, resulting in a sample of $n = 325$ participants. Finally, given that the total elapsed viewing time for all 20 commercials was 7.33 minutes, all participants who completed the task in less than eight minutes were also excluded, resulting in a study sample of $n = 318$ participants.

**Materials**

**Television commercials.** To select television commercials, researchers (including author A.E.) viewed two television networks aimed toward young women (Home and Garden Television and E! Entertainment Television) on three occasions during the day and evening. The most frequently run commercials were recorded and then 20 total commercials were selected for inclusion: 10 commercials advertised a food product and 10 advertised a non-food product. Of the food commercials, four commercials advertised fast food restaurants, three commercials advertised beverages, two commercials advertised candy, and one commercial advertised a yogurt snack with candy. With regard to non-food commercials, three commercials advertised beauty products, three commercials advertised hygiene products, and the remaining four commercials advertised a range of products from cars to credit cards. Copies of these commercials were purchased through a media agency for use in the present study.

**Valence and arousal rating survey.** Valence and arousal ratings for each commercial were gathered using an online survey based on methods established by Kurdi, Lozano, and Banaji (2017). The survey provided definitions of the terms “valence” (i.e., how positive/negative they felt after viewing the commercial) and “arousal” (i.e., how much affective intensity they felt after viewing the commercial). Participants were instructed to rate valence and arousal
separately from one another, such that commercials that were high in valence could be either high or low in arousal, and commercials that were low in valence could be either low or high in arousal. Participants were asked to rate each advertisement using a seven-point scale. Valence scales were labeled in the following way: 1 = negative, 4 = neutral/neither positive or negative and 7 = positive, and arousal was labeled as: 1 = not strongly emotional, 4 = moderately emotional, and 7 = strongly emotional. Rating scales were adapted from those used by Kurdi et al. (2017) in the development of the Open Affective Standardized Image Set (OASIS).

**Procedure**

Institutional Review Board approval was obtained from the University prior to collecting survey data. Similar to Kurdi et al. (2017), participants were recruited through Amazon Mechanical Turk (MTurk). MTurk is an online platform allowing individuals to register as “workers” to complete tasks for compensation. Researchers may then register as “requesters” and post tasks that they need to be completed. Workers can view all available tasks and choose to complete all tasks for which they are eligible. Workers complete demographic information upon registering with MTurk, and requesters can use that information to select workers with key characteristics (e.g., age, gender, education level). Over the last five years, MTurk has become a popular option for researchers conducting large-scale research that does not require an individual to come into the lab. For a more detailed overview of MTurk and its use in research (see Mason & Suri, 2011).

Information about the research study was posted on the MTurk platform and workers were allowed to sign up for the study if they met inclusion criteria (i.e., females between the ages of 18-25 currently living in the United States). After reading a short paragraph about the purpose of the study, participants were directed to follow a link to an online survey platform. Informed
consent was obtained, after which participants were given a detailed description of the definition of valence and arousal. Next, participants viewed 20 randomly presented television commercials advertising either food or a non-food product. Workers were paid a total of $2.50 for completing the survey. This amount was obtained by dividing the federal minimum wage at the time of data collection ($7.25) by the maximum amount of time estimated to read survey instructions and watch all commercials twice (20 minutes).

**Analytic Strategy**

Commercials were designated as either “food” or “non-food” based on the primary product advertised. Two-tailed paired samples t-tests were conducted to evaluate whether food and non-food commercials differed in valence and arousal. T-tests were also used to examine differences in valence and arousal ratings between commercials advertising similar categories of food and non-food products. All p-values were adjusted using Bonferroni correction to account for multiple analyses. Although participants were instructed to rate valence and arousal levels on a scale from 1-7, approximately 6% of all responses included a zero value, such that participants instead rated the commercials on a scale from 0-7. Because of this, data were transformed so that all zero values were recoded as 1 and all t-tests were conducted using transformed data. Then, identical analyses were conducted using untransformed data. Because results did not differ based on whether data were transformed, all of the following analyses are presented using original, untransformed data.

**Results**

Participants took an average of 20 minutes to complete the task ($SD = 10$ minutes). Valence and arousal levels for each commercial are presented in Tables 7 and 8. The average valence for the 10 food commercials was $M = 4.75$ ($SD = .91$). As presented in Table 7, the food
commercial with the highest rated valence was Starbucks ($M = 5.42, SD = 1.41$) and the commercial with the lowest rated valence was for KFC ($M = 4.29, SD = 1.72$). With regard to arousal, the average rating across all 10 food commercials was $M = 3.20$ ($SD = 1.22$). As can be seen in Table 8, the food commercial with the highest arousal rating was for Dove chocolate ($M = 4.68, SD = 1.75$), and the food commercial with the lowest arousal rating was for Carl’s Jr. ($M = 2.42, SD = 1.96$). Valence and arousal ratings for food commercials were moderately correlated ($rs = .31 - .46$).

Table 7. Mean Valence Ratings of Food and Non-Food Commercials

<table>
<thead>
<tr>
<th>Food Commercial</th>
<th>Mean (SD)</th>
<th>Non-Food Commercial</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starbucks</td>
<td>5.42 (1.41)</td>
<td>Degree Deodorant</td>
<td>5.44 (1.36)</td>
</tr>
<tr>
<td>Dove Chocolate</td>
<td>5.24 (1.57)</td>
<td>Volkswagen</td>
<td>5.15 (1.44)</td>
</tr>
<tr>
<td>Chobani Yogurt</td>
<td>4.84 (1.52)</td>
<td>Dove Deodorant</td>
<td>5.05 (1.48)</td>
</tr>
<tr>
<td>Diet Coke #1</td>
<td>4.85 (1.36)</td>
<td>Ulta Beauty</td>
<td>4.91 (1.60)</td>
</tr>
<tr>
<td>Pizza Hut</td>
<td>4.79 (1.33)</td>
<td>Always Feminine Products</td>
<td>4.82 (1.40)</td>
</tr>
<tr>
<td>Kit-Kat</td>
<td>4.66 (1.44)</td>
<td>Tresemme Shampoo</td>
<td>4.73 (1.20)</td>
</tr>
<tr>
<td>Taco Bell</td>
<td>4.49 (1.44)</td>
<td>MasterCard</td>
<td>4.38 (1.42)</td>
</tr>
<tr>
<td>Diet Coke #2</td>
<td>4.42 (1.27)</td>
<td>Cover Girl</td>
<td>4.34 (1.38)</td>
</tr>
<tr>
<td>Carl’s Jr.</td>
<td>4.33 (1.43)</td>
<td>Amazon Echo Dot</td>
<td>4.05 (1.63)</td>
</tr>
<tr>
<td>KFC</td>
<td>4.29 (1.72)</td>
<td>Victoria’s Secret</td>
<td>4.04 (1.61)</td>
</tr>
</tbody>
</table>
Table 8. Mean Arousal Ratings of Food and Non-Food Commercials

<table>
<thead>
<tr>
<th>Food Commercial</th>
<th>Mean (SD)</th>
<th>Non-Food Commercial</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dove Chocolate</td>
<td>4.68 (1.75)</td>
<td>Degree Deodorant</td>
<td>3.99 (1.93)</td>
</tr>
<tr>
<td>Starbucks</td>
<td>3.87 (1.91)</td>
<td>Volkswagen</td>
<td>3.66 (1.89)</td>
</tr>
<tr>
<td>Diet Coke #1</td>
<td>3.63 (1.79)</td>
<td>Amazon Echo Dot</td>
<td>3.30 (1.96)</td>
</tr>
<tr>
<td>Taco Bell</td>
<td>3.10 (1.94)</td>
<td>Ulta Beauty</td>
<td>3.26 (1.98)</td>
</tr>
<tr>
<td>Kit-Kat</td>
<td>2.97 (1.93)</td>
<td>MasterCard</td>
<td>3.17 (1.88)</td>
</tr>
<tr>
<td>Chobani Yogurt</td>
<td>2.94 (1.94)</td>
<td>Always Feminine Products</td>
<td>3.15 (1.79)</td>
</tr>
<tr>
<td>KFC</td>
<td>2.80 (1.99)</td>
<td>Dove Deodorant</td>
<td>3.12 (1.80)</td>
</tr>
<tr>
<td>Pizza Hut</td>
<td>2.79 (1.99)</td>
<td>Victoria’s Secret</td>
<td>3.01 (1.98)</td>
</tr>
<tr>
<td>Diet Coke #2</td>
<td>2.66 (1.88)</td>
<td>Tresemmme Shampoo</td>
<td>2.58 (1.82)</td>
</tr>
<tr>
<td>Carl’s Jr</td>
<td>2.42 (1.96)</td>
<td>Cover Girl Mascara</td>
<td>2.36 (1.75)</td>
</tr>
</tbody>
</table>

The 10 non-food commercials were also evaluated. The average valence for non-food commercials was $M = 4.72 \ (SD = 0.87)$. As can be seen in Table 7, the non-food commercial with the highest rated valence was Degree women’s deodorant ($M = 5.44, \ SD = 1.36$) and the commercial with the lowest rated valence was for Victoria’s Secret ($M = 4.04, \ SD = 1.61$). For arousal, the average rating across all 10 non-food commercials was $M = 3.19 \ (SD = 1.18)$. As presented in Table 8, the non-food commercial with the highest arousal rating was for Degree ($M = 3.99, \ SD = 1.93$), and the non-food commercial with the lowest arousal rating was for Cover Girl mascara ($M = 2.36, \ SD = 1.76$). Valence and arousal ratings for non-food were correlated ($r_s = .24 - .50$).
When commercial valence and arousal ratings were compared, analyses revealed that there was no significant difference in arousal, $t(318) = 0.56, p = .58$, or in valence between the food commercials and the non-food commercials, $t(318) = 1.28, p = .20$. This confirmed that our commercials were matched on these affective properties. Next, analyses evaluating differences in valence and arousal among similar commercials were conducted. T-tests indicated that there was a significant difference between the most arousing commercials and the least arousing commercials for both food ($t(318) = 15.75, p < .001$) and non-food items ($t(318) = 13.68, p < .001$). Likewise, there was also a significant difference between the most valent commercials and the least valent commercials for both food ($t(318) = 11.02, p < .001$) and non-food items ($t(318) = 13.24, p < .001$). There were also significant differences between the highest and lowest rated commercials advertising similar items within the food category. For example, when the two candy commercials were compared, the Dove chocolate commercial ($M = 4.68, SD = 1.75$) was rated as significantly more arousing than the Kit-Kat commercial ($M = 2.97, SD = 1.93; t(318) = 12.67, p < .001$). Likewise, the most highly arousing fast food commercial (Taco Bell; $M = 3.10, SD = 1.93$) was rated as significantly more arousing than the least arousing fast food commercial (Carl’s Jr.; $M = 2.42, SD = 1.96; t(318) = 5.73, p < .001$). This pattern was also observed with regard to valence. The most positively rated drink commercial (Starbucks; $M = 5.42, SD = 1.41$) was rated as significantly more valent than the lowest rated drink commercial (Diet Coke; $M = 4.42, SD = 1.27$) ($t(318) = 11.39, p < .001$). Furthermore, there was also variation between categories for the non-food commercials. For example, when the two deodorant commercials were compared, the arousal rating for Degree deodorant ($M = 3.99, SD = 1.93$) was significantly higher than the rating for Dove deodorant ($M = 3.12, SD = 1.80; t(318) = 7.84, p < .001$). This was also the case for valence, where the highest rated beauty commercial (Ulta Beauty; $M = 4.91$, SD = 1.93) was rated as significantly more valent than the lowest rated beauty commercial (Dove; $M = 3.12, SD = 1.80; t(318) = 11.43, p < .001$).
was significantly higher than the lowest rated commercial for a beauty product (Cover Girl mascara; $M = 4.34$, $SD = 1.38$) ($t(318) = 6.70, p < .001$).

**Discussion**

Advertising research often examines the impact that images have on observable behavior, but largely fails to consider the known effects of arousal and valence on subsequent behavior. The present study presents a novel and replicable method for assessing for valence and arousal to account for the impact that affect manipulation may have on individual response to advertising. Findings from this study demonstrate that (a) food and non-food advertisements can be empirically matched based on the levels of valence and arousal that they evoke, (b) advertisements for similar characteristics of products may evoke different levels of valence and arousal, and (c) advertisements that are high in valence may be low in arousal, and vice versa, and (d) the affective properties of specific advertisements can be measured in a quick and efficient manner that allows for pre-testing of primary study stimuli across advertising mediums.

**Valence and Arousal Within and Outside of Advertising Categories**

We found that there were no differences in valence and arousal between the food and non-food commercials in our study. This is important for two distinct reasons. First, these findings demonstrate the feasibility of empirically assessing the valence and arousal evoked by advertisements to be used as stimuli in subsequent behavioral research. Second, although our study represents only a small sample of the food and non-food commercials advertised on television, and do not include the specific commercials utilized in previous studies, results support the idea that affective response to commercials may not account for the persuasive nature of food commercials in influencing food intake or neurobiological response. That is, our results do not confirm the idea that food commercials specifically hold more emotional appeal than non-
food commercials. This is likely because commercials advertising other products also use themes and strategies that may be equally valent and arousing.

Although we did not find significant differences in valence and arousal between food and non-food categories, this study highlights the vast differences in valence and arousal that may exist even within commercials of the same advertising category. For example, food products that were very similar in function (i.e., candy, fast food, etc.) often had significantly different ratings in valence and arousal. These findings suggest that even if a particular research study contains commercials that all advertise similar products, (e.g., fast food), it is impossible to know, without assessment of arousal and valence, whether those advertisements will have equivalent valence and arousal ratings. Again, this lends support to the idea that there are other factors within these commercials that influenced their levels of valence and arousal, above and beyond the advertisement of food. Studies investigating behavioral or neurobiological outcomes, in particular, need to consider these factors in drawing conclusions about results.

Valence and Arousal: Orthogonal Constructs

In addition to comparing valence arousal levels across categories of commercials, we also compared differences in valence and arousal within the same commercials. Despite evidence to suggest that valence and arousal both impact visual processing and subsequent behavior (Bradley et al., 1992; Yuan et al., 2007), they may not always share a linear relationship. In the present study, the valence and arousal levels of a particular commercial were correlated; however, commercials that were among the highest in arousal were not always the highest in valence (e.g., Amazon Echo Dot). This supports the theoretical perspective that valence and arousal are orthogonal constructs and should be assessed as such (Feldman, 1995). This has important practical implications, as researchers may ask participants if they like or want a certain product
advertised in a commercial without considering how aroused they are by that product. By doing so, a critical piece of information that may influence subsequent behavior is often omitted given that highly arousing images are more likely to be remembered long-term than those that are not arousing (Bradley et al., 1992).

**Extension of MTurk Method to Other Forms of Advertising**

Given the impact of valence and arousal on behavior, it is important that a reliable and valid method for evaluating valence and arousal is also applicable to forms of advertising other than commercials. The rapid increase of advertising on the internet and social media makes it critical for researchers to also consider valence and arousal of advertisements presented on these mediums. MTurk confers the flexibility to test a wide range of images and videos quickly and efficiently. This recruitment method also minimizes the need for equipment, as participants only need access to a web browser and the capacity to view and listen to videos. Further, MTurk offers the capability to pre-test advertisements using a sample that is similar to an adult sample for a subsequent study. This allows the researcher to control for factors that may influence assessment of valence and arousal (e.g., gender or age). On a related note, it is possible to access a wide variety of participants across a number of demographic variables through the use of MTurk’s large pool of users. Despite the fast-paced nature of advertising, it is imperative to assess for valence and arousal before utilizing advertisements in research. A method such as MTurk allows the researcher to exercise due-diligence in pre-testing commercials while maintaining the speed and efficiency needed in this kind of research.

Despite the significant strengths of this method, there are also weaknesses, specifically those that are associated with the use of MTurk. First, the quality of data gathered from MTurk workers may also be variable. Some workers may click through a survey in the minimum time
possible in order to receive payment. However, this is a risk taken when administering any online survey, and there are checks and balances that can be implemented to ensure that workers are accurately responding to questions, such as verifying the amount of time taken to respond to a survey, checking to see if there is variability of responses, and inserting validation questions to test response integrity. Additionally, one major concern that has arisen over the last five years with the popularity of MTurk is the ethics of researchers using the platform. MTurk functions as a capitalist marketplace with no minimum wage regulation. Because of this, requesters often pay workers as little as possible to complete tasks. Although MTurk is a relatively inexpensive way to collect data, it is important for scientific researchers to keep in mind ethical principles when determining the price of a particular task (Fort, Adda, & Cohen, 2011). One rule of thumb that may be used is to take the amount of time it would take to complete a task and divide that by the minimum wage when setting payment. This is important both for ethics, as well as for quality assurance, as research has shown that fair payment is also associated with higher work quality (Buhrmester, Kkwang, & Gosling, 2011).

Conclusion

This paper presents a rationale for assessing valence and arousal in advertising research, and establishes a replicable method of assessment. Our findings demonstrate the variability in valence and arousal, even between advertisements for similar products, while underscoring the need to consider valence and arousal as related but orthogonal constructs. By using a large-scale, relatively fast implementation method like Amazon Mechanical Turk, this study presents an efficient method for understanding and accounting for valence and arousal. Finally, as the field of advertising research shifts towards utilizing neuroscientific methods to examine response to advertisements, the assessment of valence and arousal becomes not only prudent, but crucial.
Media effects researchers should take heed and account for valence and arousal in the stimuli used in their studies.
REFERENCE LIST


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McCue, M. C., Marlatt, K. L., Sirard, J., & Dengel, D. R. (2013). *Examination of changes in youth diet and physical activity over the summer vacation period. 11*(1).


VITA

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While at Loyola, Dr. Egbert was elected as President of the Association for Psychological Science Student Caucus, an organization representing over 15,000 psychology students across the globe. On campus, Dr. Egbert also served on several committees, including the Clinical Psychology Diversity Committee, where she helped to recruit undergraduates from underrepresented backgrounds to pursue doctoral degrees in clinical psychology.

Dr. Egbert completed her predoctoral clinical internship in pediatric psychology at the Warren Alpert Medical School of Brown University, where she is currently a post-doctoral fellow studying the treatment of eating disorders and obesity in youth.