Food for Thought: How Skipping Lunch and Psychiatric Illness Affect Cognition

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A thesis submitted to the Department of Psychology for honors

Duke University

Durham, North Carolina

2019

Abstract

Meal skipping is a common disordered eating behavior in college-aged individuals. This behavior is associated with a variety of health risks, including nutritional deficits and an increased risk for eating pathology. Research has indicated that meal skipping is also associated with impairments in various domains of cognitive functioning, including in tasks involving working memory, sustained attention, and set-shifting ability. However, a "post-lunch dip" in cognitive performance has been shown in individuals who consume lunch for approximately two hours after consumption. Possible moderating factors within the relationship between meal skipping and cognitive functioning have yet to be examined, particularly in regards to the presence of psychopathology. Both depression and anxiety symptoms have been associated with impairments in tasks involving working memory, sustained attention, set-shifting ability, and motor speed, indicating that individuals with these disorders may be particularly vulnerable to cognitive impairments seen with meal skipping behavior. This study investigated how skipping lunch affects various domains of cognitive functioning (working memory, sustained attention, set-shifting ability, and motor speed) after the post-lunch dip period in a sample of college students (aged 18-25; *N* = 99), primarily focusing on whether depression and/or anxiety symptoms moderate this relationship. Understanding the mechanisms by which meal skipping behavior affects cognition by examining potential moderating effects of common eating disorder comorbidities, such as depression and anxiety, has implications for encouraging healthier eating habits and preventing eating disorder onset in a vulnerable population.

Food for Thought: How Skipping Lunch and Psychiatric Illness Affect Cognition

Meal skipping is a common disordered eating behavior in undergraduate students, with over 8 in 10 college females reporting skipping meals for weight loss (Kelly-Weeder, 2011; Huang, Song, Schemel, & Hoerr, 1994). In fact, meal skipping has been shown to be most prevalent in young adults (aged 18-30) compared to other age groups, with prevalence estimates reaching up to 87% in this population (Pendergast, Livingstone, Worsley, & McNaughton, 2016). Meal skipping is associated with depression, nutritional deficits, and an increased risk for eating pathology (Utter, Denny, Robinson, Ameratunga, & Crengle, 2012; T.S. Rao, Asha, Ramesh, & K.S. Rao, 2008). Given the associations of skipping meals with negative physical and mental health symptoms, it is critical to better understand (1) whether skipping meals may contribute to or exacerbate mental health symptoms, (2) whether these consequences are more severe for certain vulnerable individuals, and if so, (3) to explore the mechanisms whereby this behavior confers these consequences.

Literature Review

Meal Skipping and Cognitive Functioning

Numerous studies suggest that meal skipping is associated with impairments in various domains of cognitive functioning, such as working memory, attention, and cognitive flexibility (Wesnes, Pincock, Richardson, Helm, & Hails, 2003; Pivik, Tennal, Chapman, & Gu, 2012; Gonzalez-Garrido, Brofmann-Epelbaum, Gomez-Velazquez, Balart-Sanchez, & Ramos-Loyo, 2018). Much of the literature about the effects of meal skipping on cognitive functioning focuses on skipping breakfast, which is the most frequently skipped meal. For example, one study found that in a sample of undergraduate students, 22% skipped breakfast, 8% skipped lunch, and 5% skipped dinner (Huang et al., 1994). Although young adults skip meals at the highest frequency relative to other age groups, associations with cognitive performance have mostly been studied in children and adolescents.

Effects of skipping breakfast on cognitive functioning. The literature examining associations between skipping breakfast and cognitive performance largely reflects the importance of eating breakfast to preserve performance on tasks requiring working memory, attention, and set-shifting ability, which is defined as the unconscious ability to switch one's attention between one task and another. One study using a randomized crossover design investigated the differential effects of skipping breakfast, consuming a glucose drink, and eating breakfast cereal on attention and memory in a sample of 29 school children (aged 9-16; Wesnes et al., 2003). This study found that skipping breakfast produces impairments on tasks measuring verbal and non-verbal working memory, attention, and motor speed compared to consuming a glucose drink or breakfast cereal (Wesnes et al., 2003). Similarly, a study conducted using a within-participant design compared the effects of skipping breakfast and consuming either oatmeal or cereal in a sample of 30 older children (aged 9-11) and 30 younger children (aged 6-8; Mahoney, Taylor, Kanarek, & Samuel, 2005). This study found that overall, children who consumed breakfast performed better in a spatial memory task, with girls who consumed breakfast also showing improvements in a short-term memory task relative to girls who skipped breakfast (Mahoney et al., 2005). Furthermore, in a study consisting of 20 undergraduate students, individuals who skipped breakfast had significantly fewer correct responses on three n-back working memory tasks compared to individuals who consumed breakfast, corroborating that skipping breakfast can lead to impairments in memory-related tasks (Gonzalez-Garrido, 2018). Overall, these studies showcase that the literature surrounding cognitive impairments in individuals who skip breakfast is largely unequivocal in relation to memory-related tasks.

Another study examined other cognitive impairments associated with skipping breakfast in a randomized sample of adolescents (*N* = 96; 12-15 years-old) and identified that relative to adolescents who consumed breakfast, adolescents who skipped breakfast performed worse on the Stroop Task and the Visual Search Test, which measure set-shifting ability, selective attention, and visual processing (Cooper, Bandelow, & Nevill, 2011). However, individuals who skipped breakfast performed worse than those who consumed breakfast only on the complex portion of the Sternberg Paradigm, an assessment of working memory (Cooper et al., 2011). This result may indicate that skipping breakfast produces greater impairments on the accurate completion of more cognitively demanding tasks (Cooper et al., 2011). Thus, skipping breakfast is largely associated with impairments in set-shifting ability, working memory, and attention in young populations, and these disturbances may increase with task complexity.

Effects of skipping lunch on cognitive functioning. There is a paucity of research on the effects of skipping lunch on cognitive functioning, despite evidence that lunch is also a frequently skipped meal. In a systematic review, prevalence rates of skipping lunch were found to range from 8-57%, with the omission of lunch being most common among females (Pendergast et al., 2016). However, whereas consuming breakfast is associated with better performance on executive functioning tasks compared to skipping breakfast, the consumption of lunch appears to have the opposite effect. This phenomenon is termed the "post-lunch dip" in which a decrement in cognitive performance is seen following the consumption of lunch due to normal daily fluctuations in circadian rhythms (i.e. sleeping patterns) and changes to dietary habits (Khanna & Gupta, 2012). The post-lunch dip is shown to peak one hour after consuming lunch, with studies suggesting that cognitive performance begins to recover two hours after lunch (Muller, Libuda, Terschlusen, & Kersting, 2013). This effect has been shown to vary by task, with significant impairments in performance being shown for tasks requiring focusing and sustaining attention (Khanna & Gupta, 2012).

A systematic review summarized eleven studies providing evidence for the post-lunch dip in adults over the age of 18 (Muller et al., 2013). In three studies that focused on the effects of skipping lunch on cognitive functioning, most saw impairments in some but not all cognitive assessments after lunch, with the greatest impairments being found in tasks associated with sustained attention and perceptual discrimination (Muller et al., 2013; Craig, Baer, & Diekmann, 1981; Smith & Miles, 1986; Kanarek & Swinney, 1990). One of these studies involved an experiment in which 48 university students were randomized to either a “lunch” or a “no-lunch” condition, with varied testing times, in order to identify the effects of lunch consumption on attention (The Five-Choice Serial Reaction Time Task) and set-shifting ability (The Stroop Task; Smith & Miles, 1986). Individuals who consumed lunch were shown to perform worse on the attention task compared to individuals who did not consume lunch, with no marked differences between study conditions on the Stroop Task (Smith & Miles, 1986). Additionally, two crossover studies were conducted on samples of college-aged men (N = 10; N = 8) where subjects were each tested within four conditions, the lunch/no lunch conditions being factorially crossed with the high calorie/low calorie snack conditions (Kanarek & Swinney, 1990). Findings from both experiments showed that participants who did not eat lunch, but consumed a high-calorie snack, performed better on digit span recall and sustained attention tasks compared to those who ate lunch and consumed a lower calorie snack (Kanarek & Swinney, 1990). In these studies, the consumption of lunch was associated with cognitive impairments related to attention, memory, and perceptual discrimination within the two-hour post-lunch dip period.

The effects of lunch on cognitive functioning also appeared to differ by meal size and composition. In one study measuring the effects of lunch consumption on performance in a selective attention task, individuals who consumed a large lunch made more errors than those who consumed a smaller lunch (*n* = 35; Muller et al., 2013). Individuals were also shown to respond more accurately but more slowly after a high-fat lunch compared to a low-fat lunch (*n* = 16-18; Muller et al., 2013). Additionally, slower reaction times were found in individuals who consumed a high-carbohydrate lunch compared to individuals who consumed a high-protein lunch (*n* = 184; Muller et al., 2013). These previous studies indicate that a lunch-induced dip in cognitive functioning between an hour and two hours after lunch appears to be prominent in adult populations; may be more likely to occur with the consumption of larger, high-fat or high-carbohydrate lunches; and is associated with impairments in tasks involving working memory, sustained attention, and perceptual discrimination.

Possible Moderating Factors: Eating Disorders, Depression, and Anxiety

One notable gap in the meal skipping literature is the exploration of potential moderating factors that could impact the relationship between meal skipping and cognitive performance, such as the presence of psychopathology. Given the relationship between meal skipping and the development of eating disorders, eating disorder symptoms may affect this pathway due to the cognitive impairments associated with disorders like anorexia nervosa. For example, impaired set-shifting ability and cognitive rigidity have been found to be stable phenotypes of anorexia nervosa in young adults (Holliday, Tchanturia, Landau, Collier, & Treasure, 2005). To explore this trait, one study assessed 47 pairs of sisters that were discordant for anorexia nervosa and 47 healthy, unrelated women in order to compare their performance on set-shifting (the CatBat task) and perceptual rigidity (the Haptic Illusion task) assessments (Holliday et al., 2005). Overall, sisters with and without anorexia nervosa were slower at completing the set-shifting task and exhibited greater perceptual rigidity than unrelated women (Holliday et al., 2005). Additionally, women with anorexia nervosa were slower on set-shifting tasks than healthy women, but they did not significantly differ from recovered women (Holliday et al., 2005). This finding provides evidence that set-shifting impairments are an endophenotype associated with anorexia nervosa regardless of illness stage.

Impaired set-shifting in those with eating disorders has been supported by several other studies. In one systematic review, the authors summarized 15 randomized control trials that employed neuropsychological assessments of set-shifting ability, including the Trail Making Test, Wisconsin Card Sort Test, Brixton task, Haptic Illusion, CatBat task, or the set-shifting portion of the Cambridge Neuropsychological Test Automated Battery (Roberts, Tchanturia, Stahl, Southgate, & Treasure, 2007). The Trail Making Test was used most often to assess set-shifting speed, and impairments in set-shifting ability were found to be consistent across tasks, eating disorder diagnoses, and states of illness (Roberts et al., 2007). However, the authors stated that many of the studies used small sample sizes, with studies employing samples of 72 individuals and below, indicating that future research should examine these cognitive impairments in bigger samples to increase effect sizes (Roberts et al., 2007). Given these existing cognitive vulnerabilities in individuals with eating disorders, this population may be differentially affected by engaging in meal skipping behavior, worsening the cognitive impairments that are already present.

The current study is an extension of a study conducted by Nandini Datta and colleagues (2018), which explored the effects of skipping lunch on various domains of cognitive functioning (verbal and non-verbal memory, sustained attention, and set-shifting ability) in a college-aged sample (*N* = 96), while considering dietary restraint (a subscale of the Eating Disorders Examination-Questionnaire) as a moderating factor. In this study, set-shifting impairments were found for individuals who consumed lunch compared to those who skipped lunch when eating disorder restraint scores were less than 2.26, which is indicative of lower dietary restraint (Datta et al., 2018). Differences in performance on the first two trials of a short-term memory task (Verbal Paired Associates I) were also shown between conditions, with individuals who skipped lunch recalling fewer words than individuals who did not skip lunch, but no significant interaction effect with dietary restraint scores (Datta et al., 2018). This difference in performance became insignificant for trials three and four of the short-term memory task, indicating that individuals who skipped lunch were able to learn the memorized words during later trials but experienced difficulty in immediately recalling the word pairs. These results highlight that though acute fasting may be effective in obtaining higher scores on assessments measuring set-shifting ability, this behavior is potentially ineffective over time for individuals who chronically restrict their meals (i.e. for individuals who obtain subclinical dietary restraint scores above 2.26). These results thus support existing research that cognitive impairments are associated with anorexia nervosa and provide novel results indicating that disordered eating behaviors may generate these impairments subclinically.

Other studies have found that eating disorders are associated with impairments in additional measures of cognitive functioning, including working memory, response inhibition, cognitive rigidity, and central coherence. A meta-analysis identified 32 studies comparing eating disorder groups (anorexia nervosa and bulimia nervosa) with healthy controls on several measures of cognitive functioning, including the Wisconsin Card Sorting Test, Iowa Gambling Task, Rey Complex Figure Task, the Central Coherence Index, and the Trail Making Test (Hirst, Beard, Colby, Quittner, Mills, & Lavender, 2017). Overall, individuals with anorexia nervosa showed small to moderate impairments in working memory, cognitive flexibility, and response inhibition (Hirst et al., 2017). Studies examining bulimia nervosa found moderate to large impairments within these same domains (Hirst et al., 2017). Thus, eating disorders are associated with lower performance in various measures of cognitive functioning, similar to those seen with meal skipping behavior that may precede and coincide with these illnesses. This evidence indicates that the presence of an eating disorder may affect the relationship between meal skipping and cognitive functioning in undergraduate students.

Other psychiatric illnesses, such as depression and anxiety, may also affect the relationship between meal skipping and cognitive functioning. Of note, up to 97% of individuals with eating disorders experience a comorbid disorder (Hughes, Goldschmidt, Labuschagne, Loeb, Sawyer, & Le Grange, 2013). In fact, research has supported that depression is a significant moderator in the relationship between anorexia nervosa and set-shifting impairments (Pender et al., 2014; Wilsdon & Wade, 2005). One study explored the relationship between the effects of anorexia nervosa and cognitive functioning, with depression and obsessive thoughts as potential moderating factors (Wilsdon & Wade, 2005). This study examined 22 women with anorexia nervosa, along with two control groups made up of women who were high in obsessionality (n = 20) and women who were low in obsessionality (n = 21), on their performance in the Wisconsin Card Sorting Test and Uses of Common Objects Test, measures of set-shifting and cognitive flexibility (Wilsdon & Wade, 2005). When controlling for depression, differences in scores on the Uses of Common Objects Test became significant, indicating that depression suppressed the variance in cognitive flexibility impairments within participants with anorexia nervosa (Wilsdon & Wade, 2005). Other studies have identified the isolated role of depression on cognitive functioning, indicating that depression is associated with many of the same cognitive impairments seen in individuals with eating disorders and in those who skip meals, including set-shifting, working memory, and response inhibition.

For example, in a systematic review and meta-analysis, the authors examined 30 studies related to cognitive performance in individuals with depression who were assessed with the Cambridge Neuropsychological Test Automated Battery, measuring working memory, set-shifting, and attention (Rock, Roiser, Riedel, & Blackwell, 2014). The authors identified that individuals who were both symptomatic and remitted from depression exhibited significant impairments in all tasks of working memory, attention, and set-shifting (Rock et al., 2014). Additionally, a research summary regarding cognitive functioning in individuals with depression identified 18 studies providing empirical evidence that in acute phases of depression, individuals experience impairments in response inhibition, problem solving, set-shifting ability, verbal fluency, and working memory (Hammar & Ardall, 2009). Set-shifting was reported to be the most prominent cognitive impairment in individuals with depression, but all impairments appeared to persist during periods of symptom reduction and in remitted individuals (Hammar & Ardall, 2009). Along with the deficits in cognitive functioning that have been found in individuals with depression, marked increases or decreases in appetite are included in the symptom profile of depression and are a common feature of depression in college students (Steer & Clark, 1997). Thus, the role of skipping meals in individuals with these cognitive vulnerabilities is important to explore.

There is a gap in the literature exploring the role of anxiety, another prevalent comorbid diagnosis seen in individuals with eating disorders, in the relationship between meal skipping and cognitive impairments. One such study examined the cognitive functioning of set-shifting in

270 women with anorexia nervosa and bulimia nervosa and found that individuals within the poor set-shifting group were shown to have longer illness durations, more severe eating disorder rituals, and higher levels of self-reported anxiety and depression (Roberts, Tchanturia, & Treasure, 2010). Studies have also indicated that individuals presenting with anxiety disorders exhibit impairments in many of the same domains as those with eating disorders, including cognitive flexibility, memory, set-shifting, and response inhibition, though there are some conflicting findings.

In a study investigating the relationship between cognitive functioning and anxiety within a sample of 130 youths (aged 9-17), the authors assessed the differential impact of varying degrees of anxiety symptoms on several cognitive assessments measuring working memory and attention (Murphy, Luke, Brennan, Francazio, Christopher, & Flessner, 2018). Individuals who experienced marked anxiety symptoms were reported to exhibit poorer working memory than healthy controls (Murphy et al., 2018). Additionally, youths who had higher levels of anxiety demonstrated better set-shifting than individuals with minimal anxiety (Murphy et al., 2018). Another study identified that in a sample of young adults (n = 148, aged 21-35), individuals with a lifetime history of anxiety disorders did not have significant cognitive impairments compared to their healthy peers (Castaneda et al., 2011). However, when these individuals were excluded, participants with a current anxiety disorder and lower self-reported psychosocial functioning performed worse in assessments measuring set-shifting, psychomotor processing speed, and visual working memory, compared to healthy controls (California Verbal Learning Test, Weschler Adult Intelligence Scale, and the Trail Making Test; Castaneda et al., 2011). Thus, depression and anxiety symptoms may moderate the relationship between meal skipping and cognitive functioning due to the demonstrated evidence that these disorders are associated with similar impairments in the cognitive domains of set-shifting, attention, motor speed, and memory.

Research Gaps and Study Significance

Despite the existence of lab-manipulated studies on the effects of skipping breakfast and lunch on several measures of cognitive functioning, these studies widely differ in their methodologies and in the cognitive domains they assessed, making it difficult to compare the data. The current meal-skipping literature also focuses on younger and older populations, excluding the vulnerable young adult population. Additionally, most of the studies related to lunch consumption assessed cognitive functioning during the post-lunch dip period, indicating that there is still a gap in the literature about the potential restoration of cognitive functioning after this period. Existing research also neglects potential moderating factors within the relationship between meal skipping and cognitive functioning, which may include psychiatric illnesses, such as eating disorders, depression, and anxiety.

The purpose of the current study was to further the existing literature by investigating the independent contributions of depression and anxiety in the relationship between skipping lunch and cognitive functioning. Additionally, this study addresses the aforementioned gaps in the literature by investigating the effects of skipping lunch on cognitive functioning after the post-lunch dip period and identifying whether depression and/or anxiety contribute to this relationship. To achieve these aims, undergraduate students were randomized into receiving a lower-calorie (no-lunch condition) or a higher-calorie (lunch condition) shake in order to blind them to the study condition. They were then assessed on their performance on two cognitive assessment batteries following a two-hour wait period. Given the existing literature reviewed, I anticipated that regardless of study condition, higher levels of depression or anxiety symptoms would be associated with decreased performance in all domains of cognitive functioning assessed (short-term and long-term working memory, motor speed, sustained attention, and set-shifting), with these impairments being magnified in the lunch omission condition.

Methods

Participants

A total of 99 undergraduates from Duke University gave written, informed consent to participate in this study, which was approved by the Duke University Health System Institutional Review Board. In this study, there were 33 males and 66 females (mean age = 19.69; range = 18-25 years). They were recruited using the Duke SONA Experiment Sign-Up Program, through which participants are able to sign up for available study slots and receive credits for their psychology courses. Once recruited, the participants completed a phone screening with a research assistant to assess their eligibility for the study. Participants were eligible to participate in the study if they were between the ages of 18-25 and had no dietary restrictions that would prevent them from consuming either shake. During the phone screening, the research assistant assessed the above eligibility criteria and informed participants that during the five-hour study, they would be expected to consume a meal replacement shake until completion, watch a movie during a two-hour wait period, and complete a variety of questionnaires and neuropsychological assessments. All 99 participants were considered eligible to participate in this study after it was confirmed that they met the above-mentioned requirements.

Procedure

This study involved a between-subjects design in which eligible participants were randomly assigned into one of two study conditions after completing the phone screen and consenting to participate in the study. The study condition was determined using random.org, a random number generator. A generation of a 0 would indicate placement in the lower-calorie shake condition (lunch omission condition), and a generation of 1 would indicate placement in the higher-calorie shake condition (lunch condition). Both shakes were 16-ounces and differed in content and color. The lower-calorie shake was green and 48-calories. The ingredients of the shake were spinach, water, xanthan gum, ground cinnamon, and natural peanut butter powder. Within this condition, there were 52 participants (males = 13; females = 39) with a mean age of 19.6 years. The higher-calorie shake was pink 638-calories. The ingredients of this shake were strawberries, coconut milk, banana, non-fat Greek yogurt, vanilla extract, and hemp protein powder. Within this condition, there were 47 participants (males = 20; females = 27) with a mean age of 19.78 years.

Once the participants arrived at the study location, without having eaten anything two hours prior, they were asked to review and sign a consent form. They were then asked to complete three analog scales: a hunger scale, a mood scale, and an energy scale. After completing these questions, participants were either given the lower-calorie shake or the higher-calorie shake, depending on the condition they were assigned before their visit, and were asked to consume the shake until completion. While consuming the shake, participants were asked to fill out a demographics questionnaire. Immediately after the completion of the shake, participants were instructed to watch a movie during a two-hour wait period, after which they completed the same hunger, mood, and energy scales. A trained research assistant then administered a variety of neuropsychological assessments that measured verbal and non-verbal memory, sustained attention, and set-shifting ability. After completing these assessments, participants were asked to fill out a post-questionnaire, which included measures of eating disorder symptoms, depression symptoms, and state and trait anxiety levels.

Study Measures

Hunger, mood, and energy visual analog scales. The hunger-satiety visual analog scale assessed self-report levels of hunger and satiety presented on a scale of 0-10, with 0 being "starving and beyond" and 10 being "Thanksgiving full. Very uncomfortable, maybe even painful." The mood and energy visual analog scales assess self-report levels of happiness and fatigue, respectively. For the mood scale, participants were asked to rate how happy they were at the moment of completing the item on a scale of 0-10, where 0 represented "not at all" and 10 represented "extremely happy." For the energy scale, participants were asked to rate how tired they were at the moment of completing the item on a scale of 0-10, where 0 represented "not at all tired" and 10 represented "extremely tired."

Eating Disorders Examination Questionnaire (EDE-Q). The EDE-Q is a 32-item self-report questionnaire that assesses the frequency and severity of eating disorder symptomatology and behaviors over the previous 28 days (Fairburn & Beglin, 1994). Each item is rated on a 7-point forced-choice rating scheme, in which participants are instructed to answer each question on a scale from 0 ("No days") to 6 ("Every day"). The EDE-Q is composed of a global score and four subscales: Restraint, Eating Concern, Shape Concern, and Weight Concern. The global score is calculated by averaging scores on the four subscales. A score of three or above on each subscale is indicative of clinical significance in eating disorder symptomatology (Mond, Hay, Rodgers, & Owen, 2006). The EDE-Q has demonstrated acceptable levels of internal consistency for the global score ($\alpha = 0.90$) and each of the four subscales: Restraint ($\alpha = 0.70$), Eating Concern ($\alpha = 0.73$), Shape Concern ($\alpha = 0.83$), and Weight Concern ($\alpha = 0.72$; Peterson et al., 2007).

Beck Depression Inventory-Second Edition (BDI-II). The BDI-II is a 21-item self-report measure that assesses the severity of depression symptoms in adults and adolescents over the age of 13 (Beck, Steer, & Brown, 1996). Each item is scored on a scale from 0 to 3, where 0 indicates that the symptom is "Almost Never" felt and 3 indicates that the symptom is "Almost Always" felt. Thus, scores on the BDI-II range from 0-63, where scores of 0-9 indicate minimal depression, scores of 10-18 indicate mild depression, scores of 19-29 indicate moderate depression, and scores of 30-63 indicate severe depression. When administered to a sample of college students, the BDI-II was shown to have high internal consistency ($\alpha = 0.89$; Steer & Clark, 1997). Additionally, norms were found to be higher for undergraduate females ($M = 9.81$, $SD = 8.71$) than for undergraduate males ($M = 8.22$, $SD = 8.06$; Whisman & Richardson, 2015).

State-Trait Anxiety Inventory (STAI). The STAI is a 20-item questionnaire assessing state and trait anxiety levels in adults (Spielberger, 1983). State anxiety is operationalized as a current emotional state, whereas trait anxiety represents a stable personality trait. Each item corresponds to an emotional condition of either trait or state anxiety and is rated on a 4-point frequency scale, from "Almost Never" to "Almost Always." The STAI has been found to have sound psychometric properties. The Cronbach's α ranges from 0.83 to 0.92 for state anxiety scores and 0.86 to 0.92 for trait anxiety scores (Hill, Musso, Jones, Pella, & Gouvier, 2012). Additionally, the test-retest reliability for state anxiety has been reported to range from 0.40 to 0.54, and the test-retest reliability for trait anxiety has been reported as 0.86 (Hill et al., 2012).

Neuropsychological Assessments

Weschler Memory Scale- Fourth Edition (WMS-IV): Verbal Paired Associates 1 and 2. The first part of Verbal Paired Associates is an auditory memory subtest in the WMS-IV (Weschler, 2009). In this task, participants are read four lists of word pairs, with each list containing the same word pairs in different orders. After each list is read, participants are asked to immediately recall one word from each pair. This subtest assesses the immediate recall of verbal information. The second part of Verbal Paired Associates is conducted 20 minutes after the first part and measures delayed recall and recognition of the same word pairs.

WMS-IV: Spatial Addition. The spatial addition subtest in WMS-IV measures visual-spatial memory storage and manipulation (Weschler, 2009). In this task, participants are given a grid and a stack of cards that contain either a red, blue, or a white circle on them. For each item, participants are shown patterns of red, blue, and white circles on two pages that are presented consecutively. They must then place the cards in their grid, placing a white circle where they saw a blue circle on both pages and a blue circle where they saw a blue circle on only one of the pages. They are informed to ignore the red circles.

Connors Continuous Performance Test (CPT). The CPT is a computerized task that measures impulsivity, sustained attention, and vigilance (Connors, 1995). This 14-minute assessment contains 360 trials in which participants must press the spacebar for any letter they are shown except for the letter “X.”

Delis-Kaplan Executive Functioning Scale (D-KEFS): Color Word Interference. The D-KEFS Color Word Interference subtest measures response inhibition set-shifting ability (Delis, Kaplan, & Kramer, 2001). This subtest contains four conditions. In the first condition, participants are asked to name colors of the patches on the page. In the second condition, participants are asked to read a series of color names that are printed in black ink. Condition three requires participants to name the ink color that the words are printed in, indicating that participants must inhibit the automatic response of reading the color name. The last condition measures set-shifting ability in that it requires individuals to switch back and forth between reading the word and the color of the ink that the word is printed in, depending on whether the word is inside a box. For each condition, participants are scored based on their completion times and on their uncorrected and self-corrected errors.

D-KEFS: Trail Making Test. The Trail Making Test is a subtest that measures set-shifting ability, motor speed, and visual attention. This task is comprised of five conditions: Visual Scanning, Number Sequencing, Letter Sequencing, Number-Letter Switching, and Motor Speed. In the Visual Scanning condition, participants must cross off all of the “3’s” on the page as quickly as possible, measuring psychomotor processing speed. The remaining conditions require participants to connect a series of dots as quickly and as accurately as possible. The Number and Letter Sequencing conditions require participants to connect numbers and letters in chronological and alphabetical order, respectively. In the Number-Letter Switching Task, participants are expected to switch between connecting the numbers and letters (i.e. 1-A-2-B-3-C), assessing their ability to flexibly switch their attention on the ordering of the numbers and letters. The Motor Speed condition requires participants to connect circles along a dotted line as quickly as possible, making sure to hit all of the circles in order.

Results

In the present study, participants were blinded and randomized into either a lunch condition (higher-calorie shake), or a lunch omission condition (lower-calorie shake). The independent contributions of depression and anxiety symptoms on the relationship between skipping lunch and cognitive functioning were analyzed using individual participant’s results on a variety of neuropsychological tests of memory and executive functioning taken from the Weschler Memory Scale – Fourth Edition and the Delis-Kaplan Executive Function System. Participant’s scores on self-report measures of depressive (BDI-II) and state/trait anxiety (STAI) symptoms were used to determine intensity of psychiatric symptoms. We anticipated that in both study conditions, higher levels of depression or anxiety symptoms would be associated with decreased performance in all domains of cognitive functioning (short-term and long-term working memory, motor speed, sustained attention, and set-shifting), with these impairments being magnified in the lunch omission condition. Descriptive statistics for the two experimental groups with respect to BDI-II scores and STAI scores are included in Table 1. Significant correlations were found between BDI-II and STAI scores, supporting that these variables should be analyzed independently (see Table 2).

Table 1

Means and Standard Deviations for Scores on the BDI-II and STAI by Experimental Group

	Lunch n = 52	Lunch Omission n = 47
BDI-II	8.12 (7.99)	7.17 (7.22)
STAI-State Anxiety	32.71 (10.67)	33.55 (9.95)
STAI-Trait Anxiety	37.81 (12.06)	38.74 (12.80)

Note. Standard deviations appear in parentheses next to means. There were no significant differences between groups with respect to these scores ($p > 0.05$).

Table 2

Pearson Correlations between BDI-II, STAI-Trait Anxiety, and STAI-State Anxiety Scores

	BDI-II	STAI-State Anxiety	STAI-Trait Anxiety
BDI-II	-	-	-
STAI-State Anxiety	0.30*	-	-
STAI-Trait Anxiety	0.42*	0.77*	-

*$p < 0.01$

Investigating Depression as a Moderating Factor

To analyze the contribution of depression on the relationship between skipping lunch and cognitive functioning, linear regressions were conducted using the meal manipulation and BDI-II scores as predictors of scaled scores on the cognitive assessments. The analyses were run both with BDI-II scores as a continuous variable and with BDI-II scores as a dichotomous variable split by scores above (n = 84) and below 13 (n = 15), which is the clinical cutoff between minimal and mild depression. In a model examining the outcome variable of long-term working memory recall scores within Verbal Paired Associates II (VPA II), the predictor of study condition was entered first, then BDI-II scores, followed by the interaction of BDI-II scores and study condition. When BDI-II scores were entered as a continuous variable, they were shown to significantly moderate the relationship between the study condition (lunch or lunch omission) and scores on the VPA II long-term working memory recall task, though there was not a significant main effect of BDI-II scores on long-term memory recall scores (see Table 3). However, the interaction effect between BDI-II scores and the study condition did not appear to explain a high proportion of the variation in long-term working memory recall scores. Contrary to the hypotheses, at higher BDI-II scores, participants who skipped lunch performed better on the long-term memory task than individuals who did not skip lunch, with these results being reversed at BDI-II scores less than 10 (see Figure 1). When entering BDI-II scores as a dichotomous variable, there were neither main effects of study condition ($\beta = -0.52$, $p > 0.05$) or BDI-II scores ($\beta = 0.03$, $p > 0.05$) nor a significant interaction effect between BDI-II scores and study condition ($\beta = 1.81$, $p > 0.05$) when predicting long-term working recall scores.

Table 3

Linear Regression Results Predicting Long-Term Memory Scores with Study Condition and BDI-II Scores

	β	Standard Error	*T*	*p*
BDI Score	-0.02	0.03	-0.69	0.54
Study Condition	-1.19	0.53	-2.23	0.03*
BDI Score x Study Condition	0.11	0.05	2.24	0.03*

Note. $R^2 = 0.07$, $F(3,94) = 2.43$, $p = 0.07$, Cohen's $f^2 = 0.08$
*$p < 0.05$

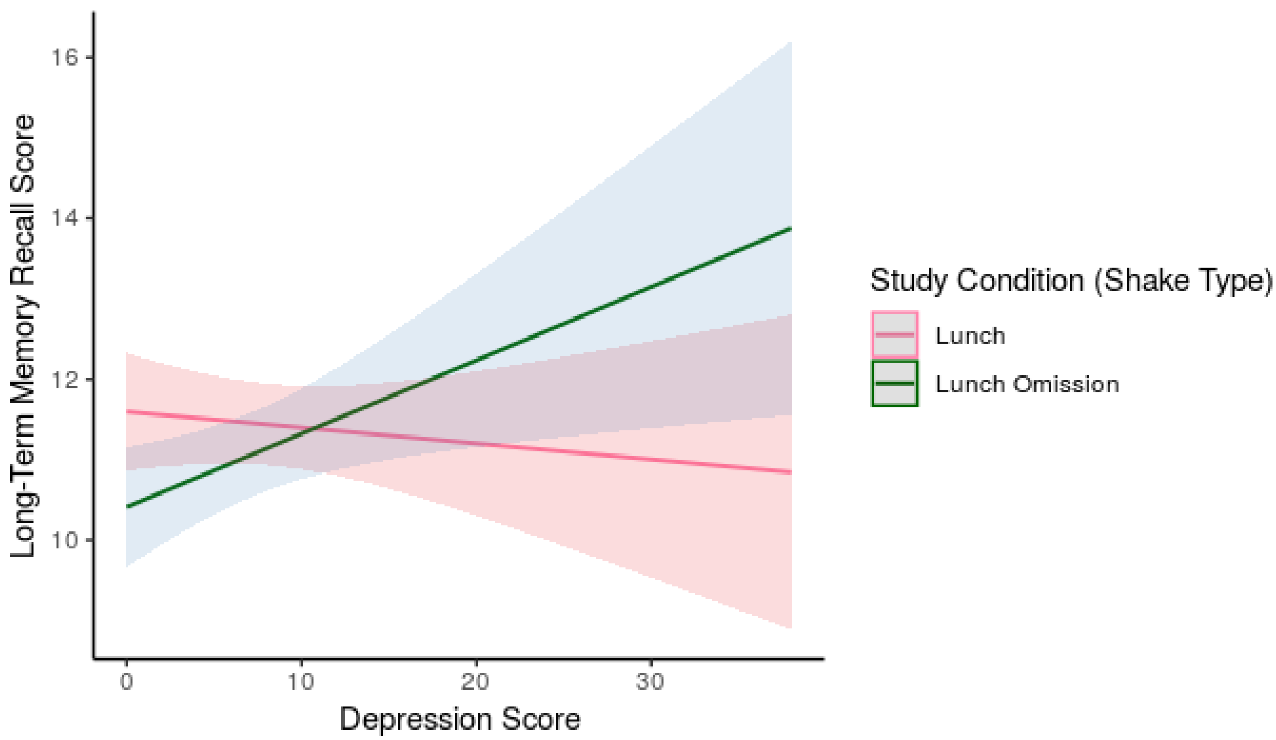

Figure 1. Depression as a moderator in the relationship between skipping lunch and long-term memory recall. The shaded area represents 95% confidence intervals.

In a model examining the outcome variable of set-shifting scores on the third condition of the Color Word Interference task, the predictor of study condition was entered first, then BDI-II score, followed by the interaction of BDI-II and study condition. When the BDI-II scores were dichotomized, the BDI-II variable was shown to be a significant moderator in the relationship between skipping lunch and set-shifting scores. BDI-II scores were also shown to have a significant main effect on set-shifting scores. However, the interaction between BDI-II scores and the study condition did not explain a high proportion of the variance in set-shifting scores (see Table 4). As shown in Figure 2, for BDI-II scores 13 and below (minimal depression), participants in the lunch condition scored slightly higher in the set-shifting task compared to participants in the lunch omission condition. For BDI-II scores above 13 (mild-severe depression), participants in the lunch omission condition scored higher in the set-shifting task compared to participants in the lunch condition. Thus, these results did not support the hypotheses and indicated that at higher levels of depression, skipping lunch was associated with faster set-shifting performance compared to eating lunch. When entering BDI-II scores as a continuous variable, there were no main effects of study condition (β = -0.62, $p > 0.05$) or BDI-II scores (β = -0.06, $p > 0.05$). Additionally, there was no significant interaction effect between BDI-II scores and study condition when predicting set-shifting scores (β = 0.09, $p > 0.05$).

Table 4

Linear Regression Results Predicting Set-Shifting Scores with Study Condition and BDI-II Scores

	β	Standard Error	*T*	*p*
BDI Score (> 13)	-1.55	0.74	-2.08	0.04*
Study Condition	-0.42	0.48	-0.87	0.38
BDI Score x Study Condition	2.96	1.36	2.18	0.03*

Note. $R^2 = 0.06$, $F(3,94) = 1.96$, $p = 0.13$, Cohen's $f^2 = 0.06$
*$p < 0.05$

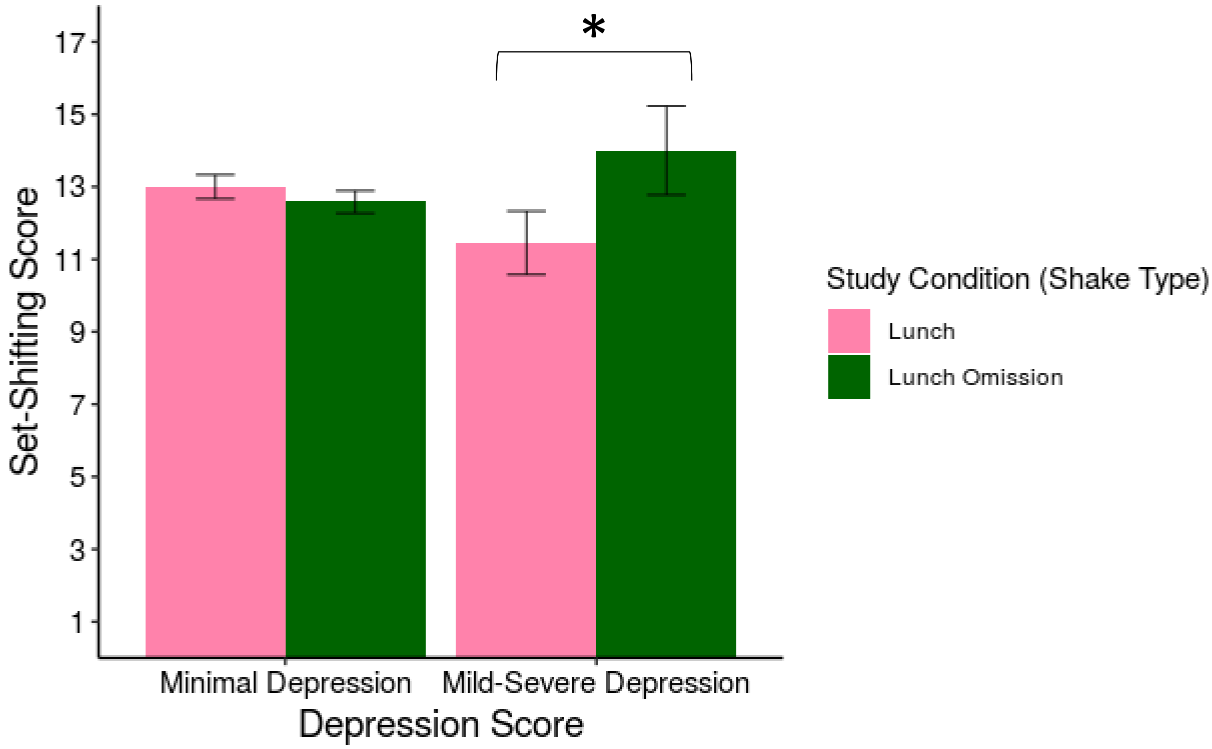

Figure 2. Depression as a moderator in the relationship between skipping lunch and set-shifting ability. Each error bar was constructed using one standard error from the mean.

In a model examining the outcome variable of motor speed scores on the first condition of the Trail Making Test, the predictor of study condition was entered first, then BDI-II score, followed by the interaction of BDI-II and study condition. When BDI-II scores were dichotomized, they were shown to significantly moderate the relationship between the study condition and motor speed scores, with no significant main effects. The interaction between depression scores and the study condition was also shown to explain much of the variance in motor speed scores (see Table 5). At BDI-II scores of 13 and below, there were no differences in motor speed task performance between the lunch and lunch omission conditions. When BDI-II scores were above 13, individuals in the lunch condition performed better than individuals in the lunch omission condition on the motor speed task, supporting the study hypotheses (see Figure 3). Similar results were attained when entering BDI-II scores as a continuous variable, with a significant moderation effect between BDI-II scores and study condition (β = 0.04, $p < 0.01$) but no significant main effects for BDI-II scores (β = -0.02, $p > 0.05$) or study condition (β = 0.45, $p > 0.05$). The predictors of study condition, BDI-II scores as a continuous variable, and their interaction explained a significant amount of the variance in motor speed scores ($R^2 = 0.20$, $F(3,92) = 7.43$, $p = 0.0001$).

Depression symptoms were not shown to significantly moderate the relationship between skipping lunch and the following domains of cognitive functioning: sustained attention, more complex measures of set-shifting ability within the fourth condition of the Trail Making Test or the last task of Color Word Interference, spatial memory, or short-term working memory ($p > 0.05$).

Table 5

Linear Regression Results Predicting Motor Speed Scores with Study Condition and BDI-II Scores

	β	Standard Error	*T*	*p*
BDI Score (> 13)	-0.22	0.51	-0.43	0.67
Study Condition	-0.16	0.33	-0.49	0.63
BDI Score x Study Condition	-3.31	0.94	-3.53	0.001*

Note. $R^2 = 0.19$, $F(3,92) = 7.43$, $p = 0.0002$*, Cohen's $f^2 = 0.24$
*$p < 0.01$

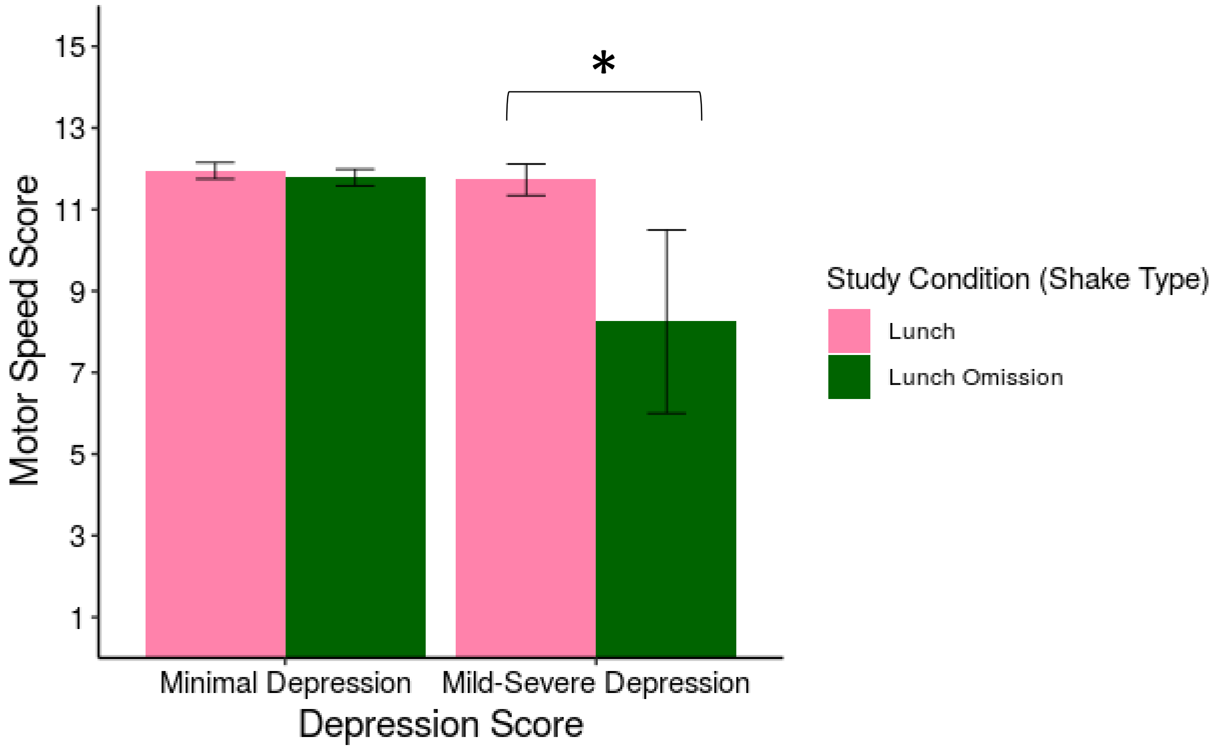

Figure 3. Depression as a moderator in the relationship between skipping lunch and motor speed score. Each error bar was constructed using one standard error from the mean.

Investigating Anxiety as a Moderating Factor

Linear regression models were conducted to identify if trait and/or state anxiety were significant moderators in the relationship between skipping lunch and cognitive functioning. Trait and state anxiety scores were split up into dichotomous variables for scores above and below 39, which is the STAI cutoff for clinical significance for both trait and state anxiety. Trait anxiety was shown to be a significant moderator in the relationship between skipping lunch and cognitive functioning only in relation to performance on the fourth condition of the Trail Making Test measuring set-shifting ability. In a model predicting set-shifting scores on the fourth condition of the Trail Making Test using trait anxiety symptoms and study condition, the predictor of study condition was entered first, then the dichotomized STAI-Trait Anxiety score, followed by the interaction of STAI-Trait Anxiety score and study condition. As shown in Table

6, a significant interaction effect between trait anxiety score and study condition was found when predicting set-shifting scores on the fourth condition of the Trail Making Test, but this interaction did not explain a high proportion of the variance in set-shifting scores. For trait anxiety scores less than 39, participants in the lunch condition scored higher on the set-shifting task compared to participants in the lunch omission condition. When trait anxiety scores were greater than 39, participants in the lunch omission condition performed better than those in the lunch condition on the set-shifting task, which did not support the study hypotheses (see Figure 4).

Neither trait nor state anxiety were significant moderators in the relationship between skipping lunch on other measures of cognitive functioning, including short-term and long-term working memory, spatial memory, motor speed, sustained attention, and the set-shifting tasks of the Color Word Interference subtest ($p > 0.05$).

Table 6

Linear Regression Results Predicting Set-Shifting Scores with Study Condition and STAI-Trait Anxiety Scores

	β	Standard Error	*t*	*p*
STAI-Trait Anxiety Score (> 39)	-1.12	0.55	-2.03	0.04*
Study Condition	-1.28	0.53	-2.42	0.02*
Trait Anxiety Score x Study Condition	1.96	0.79	2.49	0.01*

Note. $R^2 = 0.07$, $F(3,92) = 2.48$, $p = 0.07$, Cohen's $f^2 = 0.08$
$^*p < 0.05$

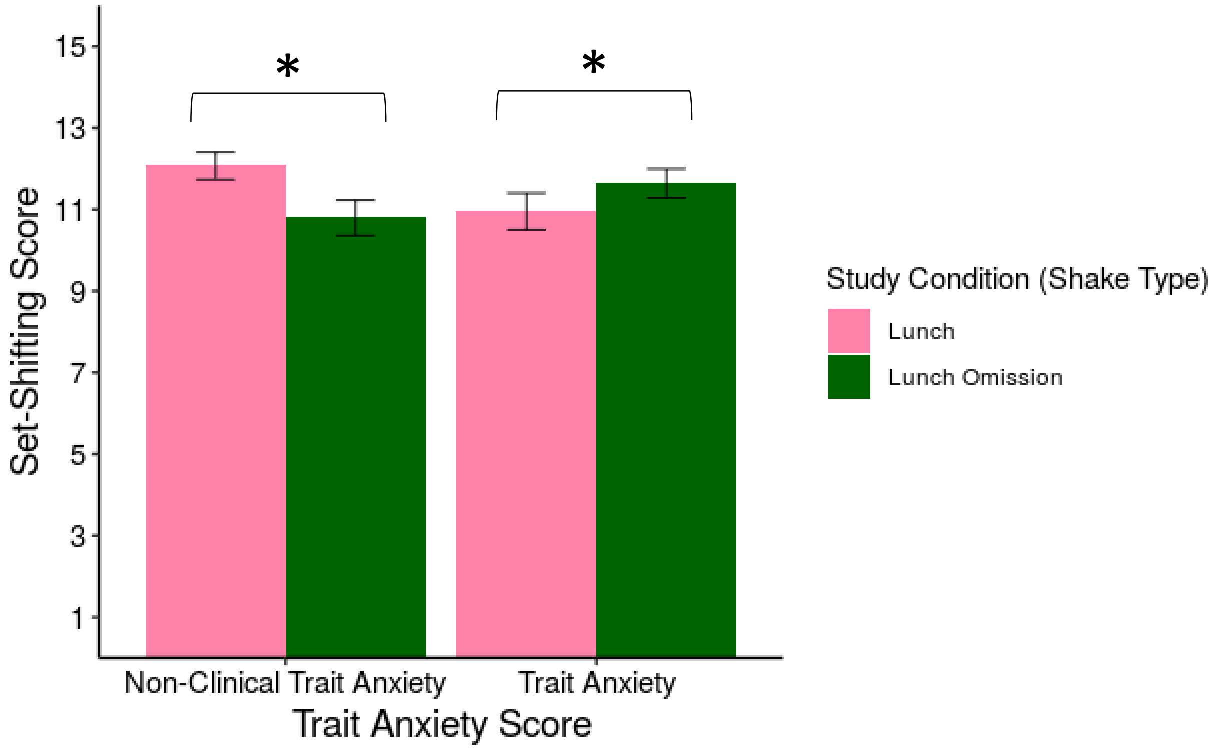

Figure 4. Trait anxiety as a moderator in the relationship between skipping lunch and set-shifting score. Each error bar was constructed using one standard error from the mean.

Discussion

The objective of the present study was to examine whether depression and anxiety symptoms moderate the relationship between skipping lunch and cognitive functioning. Given the existing literature on skipping lunch and cognitive functioning, it was assumed that after the post-lunch dip period, lasting approximately two hours post-consumption, cognitive functioning would be restored in individuals who consumed lunch and would surpass that of individuals who skipped lunch. Thus, acknowledging the existing literature, which indicates that individuals with heightened depression or anxiety symptoms generally perform worse on measures of cognitive functioning compared to healthy individuals, it was hypothesized that participants with high BDI-II and STAI scores would perform worse on measures of cognitive functioning in both study conditions compared to healthy individuals, with marked reductions in performance in the lunch omission condition (Rock et al., 2014; Hammar & Ardall, 2009).

Though significant differences were only found between study conditions for individuals with mild-severe depression symptoms (BDI-II scores > 13), the hypothesis was partially supported when investigating depression as a moderator on the relationship between skipping lunch and the first condition of the Trail Making Test, indicating that visual scanning and motor speed may be slower in individuals with depression and that these impairments may worsen when skipping lunch. This result is limited by the wide standard error in motor speed scores within the lunch omission condition for individuals with mild-severe depression, which could be explained by low statistical power and the limited number of subjects (n = 15) who reported having mild-severe depression symptoms. Additionally, this result should be interpreted with caution because depression symptoms did not significantly moderate the relationship between study condition and the fifth task of the Trail Making Test, which also measures motor speed.

Overall, the remaining results did not support the study hypotheses and instead indicated that higher depression symptoms were associated with better performance on Verbal Paired Associates II (long-term working memory recall) and on the third condition of Color Word Interference (set-shifting ability) for participants in the lunch omission condition compared to individuals in the lunch condition. Additionally, no significant main effects of BDI-II scores were found for long-term memory recall performance, set-shifting ability, short-term memory, or sustained attention. There is a current gap in the literature in terms of the differential post-lunch dip processes in clinical populations, but one may reasonably anticipate that these results indicate that the post-lunch dip in cognitive performance is extended for individuals with heightened depression symptoms, resulting in lower performance for these individuals when they consume lunch compared to when they skip lunch. Another explanation is that only 15 individuals in the sample had mild-severe BDI-II scores, resulting in limited power to detect differences between study conditions within this group.

Alternative possibilities in regards to appetite-related differences in individuals with depression were explored by investigating whether or not participant answers to the appetite BDI-II question, which ranged from 0 ("I have not experienced any change in my appetite") to 3 ("I have no appetite at all or I crave food all the time") were significant predictors of scores on the set-shifting and long-term working memory tasks. When running these analyses, BDI-II appetite scores did not significantly predict set-shifting or long-term working memory scores and they did not moderate the relationship between study condition and cognitive performance in these domains ($p > 0.05$). Similar effects were seen when including changes in satiety pre- and post-lunch consumption in the regression models with the interaction effect between BDI-II scores and study condition to detect whether or not impairments in interoception, or the ability to sense the physiologic condition of the body (i.e. hunger/fullness), could explain these differences in individuals with depression ($p > 0.05$). Thus, further research should be conducted with a clinical comparison group of individuals with depression in order to determine whether or not the post-lunch dip in cognitive performance is extended in this population compared to healthy individuals.

Similar to the results received for depression symptoms, individuals in the lunch omission condition had superior performance on the fourth task of the Trail Making Test relative to individuals in the lunch condition, but only when their STAI-trait anxiety scores were above the clinical threshold of 39. For participants who scored below this threshold, participants in the lunch condition had superior performance when compared to participants in the lunch omission condition. Though there was a novel moderation effect between trait anxiety and meal skipping, this result did not support the hypotheses or existing literature, which indicated that high anxiety symptoms are associated with poorer cognitive functioning compared to low anxiety symptoms (Castaneda et al., 2011).

Given these moderation effects of depression and trait anxiety symptoms, a potentially intriguing hypothesis is that acute food restriction and the biochemical changes associated with such restriction (e.g., lower blood glucose, dysregulated cortisol secretion) result in acute cognitive enhancing effects, at least in the short term (Witbracht, Keim, Forester, Widaman, & Laugero, 2015). In fact, individual differences in response to an acute fast may be an interesting hypothesis to explore in terms of the reinforcing value of disordered eating behaviors and the reported high comorbidity between depression, anxiety, and eating disorders. For example, in one study, 52 college students (34 male) retrospectively reported on their mood, attention, and energy during the preceding 24 hours during a self-initiated fast in honor of the Yom Kippur Jewish Holiday (Zucker, Watson, Bulik, Merwin, & Yoskowitz, 2013). A small subset (7.6%) reported improvements in attention during the fast. It is thus interesting to consider whether for some, the comorbidity of depression, anxiety, and eating disorder symptoms is reinforced in part, by changes in cognition ascribed to disordered eating patterns. Designs that examine symptom courses longitudinally and that tease apart acute versus chronic effects of food restriction are needed to fully address these questions.

Additionally, the results of this study did not replicate the results of existing research in that depression symptoms were not associated with impairments in short-term working memory, sustained attention, or other measures of set-shifting and motor speed, nor did they moderate the relationship between study condition and performance in these domains. The lack of a clinical comparison group and low sample size, with only 15 individuals meeting criteria for depression, indicates that the statistical power may have been insufficient to detect differences in cognitive functioning between study conditions and between individuals with and without depression. Another explanation is that, given that the sample was recruited from Duke University, the high-performing nature of the students who volunteered to participate in the study may lend towards higher performance in the cognitive assessments for individuals with and without depression in both study conditions, skewing the study results. Since undergraduate students are vulnerable to disordered eating behaviors like skipping lunch, it is possible that these students were accustomed to skipping meals and thus, no difference was found between individuals who skipped lunch and individuals who consumed lunch. Including a food diary or measure of meal-skipping frequency within the study questionnaire is an avenue for further exploration of this phenomenon in order to differentiate the effects of chronic versus acute food restriction on cognitive functioning.

Though previous literature has demonstrated that anxiety is associated with impairments in tasks related to sustained attention, working memory, and motor speed, trait anxiety was not associated with performance on tasks related to these domains (Murphy et al., 2018; Castaneda et al., 2011). Similarly, state anxiety was not associated with performance in any of the neuropsychological assessments. A possible reason for these results is that this sample of Duke undergraduates had high levels of trait anxiety, or stable tendencies to report anxiety, with 44 of 99 study participants meeting the clinical cut-off for trait anxiety symptoms. Existing research has shown that high trait anxiety is associated with better academic performance in high-performing individuals (Chapin, 1989). Thus, it is reasonable to assume that Duke students may be high-functioning despite high levels of trait anxiety given the rigorous academic requirements at the university. Additionally, 26 of the study participants met criteria for state anxiety, measuring their levels of anxiety during the study. Though the effects of state anxiety on academic performance have not been thoroughly explored in college-aged individuals, high levels of state anxiety have generally been associated with cognitive impairments in set-shifting and attention-related tasks (Derakshan, Smyth, & Eysenck, 2009). Given that high levels of state anxiety did not have a significant effect on cognitive functioning in the sample, this study may have been underpowered to detect differences between individuals with and without state anxiety or, alternatively, Duke students may be high-functioning despite high levels of state anxiety. To address these limitation, including a clinical comparison group of individuals with anxiety in a future study would enhance the interpretability of these results.

To conclude, understanding the mechanism by which disordered eating behaviors impact the cognition of a particularly vulnerable population, college students, has wide implications in dietary recommendations that can be given to this population for the prevention of negative health outcomes, such as eating pathology. In addition, the ways in which depression and anxiety symptoms, prevalent comorbidities of eating disorders, influence the relationship between skipping meals and cognitive functioning appear to be more complex than what was hypothesized. For example, depression and trait anxiety appear to be implicated in this relationship, albeit for some and not all domains of cognitive functioning that were assessed. Additional research should be conducted to identify whether or not depression and anxiety symptoms affect the relationship between skipping lunch and cognitive functioning as well as to examine how acute versus chronic dietary restriction may be associated with conflicting results.

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