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Los Angeles

Healthy Comfort Eating: Origins and Consequences

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Psychology

by

Laura Elizabeth Finch

2018

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ABSTRACT OF THE DISSERTATION

Healthy Comfort Eating: Origins and Consequences

by

Laura Elizabeth Finch
Doctor of Philosophy in Psychology
University of California, Los Angeles, 2018
Professor Ayako Janet Tomiyama, Chair

Many Americans eat unhealthy, high-calorie/fat/sugar foods when stressed, yet little is known about whether this *unhealthy comfort eating* actually comforts. Additionally, prior research has not tested whether *healthy comfort eating* of fruits and vegetables might also alleviate stress, or whether comfort eating before or after a stressful event is more beneficial for stress relief. Accordingly, Study 1 experimentally tested whether healthy and unhealthy comfort eating would reduce acute psychophysiological responses to a socially evaluative stressor. Following a 2 x 2 + 1 design, participants (N = 150 women) were randomized to consume one of their top-rated *healthy* or *unhealthy* foods either *before* or *after* the stressor, or consumed *no food*. Psychological, neuroendocrine, and autonomic stress responses were examined. Findings revealed that healthy and unhealthy comfort eating did not dampen reactivity or enhance recovery of psychophysiological stress compared to control, and no differences were found by comfort eating type or timing. In a sample of 100 men and women, Study 2 evaluated whether individuals can *learn* to experience healthy foods as comforting, with the aim of also promoting

healthy food intake. Applying Pavlovian conditioning methodology, intervention participants repeatedly paired together a relaxation activity and fruit intake for 7 days, whereas control participants completed these activities separately. At post-intervention, results showed that fruit intake acutely improved mood—but not autonomic stress markers—to a greater extent among the intervention group than the control group. There were no group differences in post-intervention intake of healthy and unhealthy foods outside of the lab, or in pre- to post-intervention changes in psychological outcomes, perceptions of fruit pleasantness, or intentions to buy fruits in the future. In conclusion, unhealthy comfort eating does not appear to benefit human psychophysiological stress responses. Healthy foods may not initially reduce stress, but they may acutely repair negative mood with training. Overall, healthy comfort eating may avoid potential drawbacks of unhealthy comfort eating (e.g., links with obesity) while also improving nutrition. These findings leave the door open for larger-scale interventions to transform unhealthy comfort eating to healthy comfort eating, thereby reducing negative emotion, promoting fruit intake, and decreasing chronic disease risk.

The dissertation of Laura Elizabeth Finch is approved.

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Introduction

Stress is defined as a relative imbalance between demands and resources, such that external demands are appraised as exceeding one's ability to cope (Lazarus & Folkman, 1984). Nationally representative data indicate that stress is pervasive in the United States, and in a behavior known as *comfort eating*, many people respond to stress (and/or other negative emotions) by increasing general food intake or intake of particular foods (American Psychological Association, 2016). Some individuals preferentially increase intake of high-calorie/fat/sugar foods when exposed to stress, a behavior I term *unhealthy comfort eating*.

As reviewed here, scholars have typically assumed that comfort foods must be high-calorie/fat/sugar foods, as it is well established that both human (O'Connor, Jones, Conner, McMillan, & Ferguson, 2008; Wardle, Steptoe, Oliver, & Lipsey, 2000; Zellner et al., 2006) and non-human animals (Dallman et al., 2003; Dallman, Pecoraro, & la Fleur, 2005) tend to eat more of these foods when stressed. Furthermore, accumulating research in rodents has shown that consumption of these foods dampens both behavioral and physiological stress responses (Finch & Tomiyama, 2014) although no known prior studies have examined causal effects of unhealthy comfort eating on psychophysiological stress processes in humans.

Despite this evidence that unhealthy comfort eating is common and seems to decrease stress responses (at least, in rodents), this behavior may also carry drawbacks in terms of physical health outcomes. For example, research in rodent models has found that chronic unhealthy comfort eating yields visceral fat accumulation (Dallman et al., 2005), which is associated with negative outcomes such as hypertension and cardiovascular disease (Björntorp, 1990). Relatedly, data from various human studies has indicated that comfort eating is linked to greater Body Mass Index (BMI; Finch & Tomiyama, 2015; Konttinen, Männistö, Sarlio-

Lähteenkorva, 2011; Nolan, Halperin, & Geliebter, 2010). In addition, traditional unhealthy comfort eating can be accompanied by high intake of refined carbohydrates and excessive dietary sugar consumption, which are each linked to increased risk of coronary artery disease (Johnson et al., 2009; Liu et al., 1999).

Given this, some researchers have conceptualized comfort eating as a maladaptive behavior and designed interventions to eliminate it (Daubenmier et al., 2011; Katterman, Kleinman, Hood, Nackers, & Corsica, 2014). However, comfort eating may be difficult to eradicate, as eating is hedonically rewarding (Adam & Epel, 2007) and food cues have become so abundant in the modern living landscape that it is now commonplace for scholars to describe the everyday environment as "toxic" and "obesogenic." Thus, rather than attempting to eliminate comfort eating altogether, I suggest that researchers should explore methods for harnessing the benefits of comfort eating for stress reduction without concurrently eliciting adverse health outcomes. Study 1 investigates *healthy comfort eating*—defined as eating whole fruits and vegetables in response to stress—as a means for dampening psychophysiological stress responses while consuming lower amounts of calories, fat, and sugar compared to traditional unhealthy comfort foods.

Here, I will also discuss of several plausible mechanisms through which healthy foods might comfort. Although rodent models suggest that the calorie and macronutrient content of unhealthy comfort foods are a primary mechanism driving stress dampening, I posit that learned associations between eating and stress reduction might be another mechanism explaining stress buffering in humans. Thus, Study 2 focuses on using Pavlovian conditioning methodology to forge learned associations between healthy food and stress reduction, with the aim of ultimately increasing liking and intake of healthy foods.

Stress and its Effects

Health psychologists have defined stress as a relative imbalance between demands and resources, such that external demands are appraised as exceeding one's ability to cope (Lazarus & Folkman, 1984). Stress is pervasive in the United States; nationally representative data from the American Psychological Association (2016) indicate that on average, American adults report a moderate level of stress, and 34% of Americans report that their stress has increased over the past year. There are many dimensions on which stressors can be categorized, one of which is stressor chronicity. Acute stressors are discrete events with a clear beginning and end, such as an academic exam, car accident, or robbery. Chronic stress is defined as ongoing, enduring demands that threaten to exceed the resources of an individual in areas of life such as family, marriage, parenting, work, health, housing, and finances (Dunkel Schetter & Dolbier, 2011).

As a part of the normal acute stress response, two main physiological systems react: the autonomic nervous system (ANS) and the hypothalamic-pituitary-adrenal (HPA) axis. Within the ANS response to acute stress, activation of the sympathetic nervous system (SNS) tends to increase, whereas activation of the parasympathetic nervous system (PNS) tends to decrease (Boesch et al., 2014). Health psychologists commonly assess stress-induced ANS activation using measures such as electrodermal activity, cardiovascular activity (e.g., heart rate variability, respiration, pre-ejection period, and cardiac output), and blood pressure responses (Mendes, 2009). HPA axis activation begins with the release of corticotropin-releasing hormone (CRH), which stimulates the release of adrenocorticotropic hormone (ACTH) from the anterior pituitary gland. ACTH then travels through the bloodstream to the adrenal cortex located atop the kidneys, where it stimulates the secretion of glucocorticoids (i.e., cortisol in humans; corticosterone in rodents; Lovallo & Thomas, 2000). Researchers interested in HPA activation in rodents might

choose to assess any of these outflows; however, human studies tend to focus on various types of cortisol assessment, as cortisol can be measured non-invasively via the urine, hair, or saliva.

Both psychological and physiological stress measures are known to predict health outcomes. As reviewed by Miller, Chen, and Cole (2009), prospective epidemiologic studies have shown that high levels of chronic stress predict increased morbidity and mortality from a variety of diseases such as respiratory infection, cardiovascular disease, and HIV/AIDS. In addition, stress has been shown to facilitate cascades of pro-inflammatory gene expression that promote coronary disease, autoimmune disorders, and infectious diseases (Miller et al., 2009). Furthermore, there is evidence that stress prospectively predicts weight gain (Tomiyama, Puterman, Epel, Rehkopf, & Laraia, 2013), and two-thirds of American adults are currently overweight or obese (Ogden, Carroll, Kit, & Flegal, 2014). In addition, frequent stress-induced activation of physiological allostatic systems or failure to shut off allostatic activity after stress can lead to disease over long periods of time (McEwen, 1998). Measures of HPA axis functioning are important markers to examine because profiles of HPA dysregulation have been tied to health outcomes (Golden et al., 2013). For example, higher levels of 24-hour urinary cortisol in older adults have been shown to strongly predict greater cardiovascular mortality six years later, such that those in the highest tertile of 24-hour cortisol had five times the risk of cardiovascular mortality compared to those in the lowest tertile (Vogelzangs et al., 2010). Moreover, data from 1,002 participants in the Multi-Ethnic Study of Atherosclerosis indicated that women with versus without diabetes had significantly higher total cortisol area under the curve (Champaneri et al., 2012). Given these and other well-established harmful effects of stress on physical health, it is important for researchers to investigate techniques for reducing stress.

Comfort Eating: Prevalence, Characteristics, and Effects

Many Americans respond to stress (and other negative emotions) by eating high-calorie/fat/sugar foods. This construct of *comfort eating* behavior is distinct from *emotional eating*, as the latter term can refer to eating in response to positive emotions, in addition to negative emotions (Tomiyama, Finch, & Cummings, 2015). Comfort eating is a relatively common behavior; in nationally representative data collected in 3,361 American adults in 2015, 39% of adults reported overeating or eating unhealthy foods because of stress in the past month (American Psychological Association, 2016). Although comfort eating is the focus of this review, I also note that there are individual differences in how stress impacts food intake; for example, 31% of adults report skipping meals in response to stress (American Psychological Association, 2016), and approximately 33% of adults report that their appetite is not influenced by stress (Kandiah, Yake, & Willett, 2009). In addition, evidence from multiple studies has suggested that women are more likely report engaging in comfort eating than men (American Psychological Association, 2012; Greeno & Wing, 1994; Zellner et al., 2006).

Comfort eating researchers have typically assumed that comfort foods must be high in calories, fat, or sugar. Supporting this notion is a well-established cross-species literature demonstrating that animals tend to prefer high-calorie/fat/sugar foods when exposed to stress. First considering naturalistic human studies, daily diary data have indicated that daily hassles are associated with both increased intake of high-fat/sugar snacks and decreased consumption of main meals and vegetables, with the former association being stronger in females than males (O'Connor et al., 2008). In addition, data from a within-subjects study in 90 working men and women showed that participants reported greater intake of total energy, saturated fat, and sugar during naturally-occurring high- versus low-work stress periods (Wardle et al., 2000).

Given that daily hassles and high workload ostensibly leave less time for other activities such as grocery shopping and food preparation, it seems plausible that convenience of food consumption may be one factor explaining increased stress-induced consumption of high-calorie/fat/sugar snack foods. This notion is supported by preliminary evidence from a pilot study I conducted in 73 undergraduate young women, wherein participants rated a list of 19 food/eating characteristics (e.g., salty, filling, warm, habit) on how important they were in determining "whether a food is a comfort food for you, personally" (1 = *not at all important* to 7 = *very important*). Results showed that the factor of "availability/closeness to you at the time of consumption" emerged as the most important comfort food characteristic (M = 5.22), followed by "minimal or no time required to prepare" (M = 5.08) and "sweet taste" (M = 4.81). Thus, these preliminary data indicate that convenience associated with eating certain foods might contribute to perceptions of those foods as comforting. However, even after holding constant factors related to food/eating convenience across both healthy and unhealthy foods in the laboratory, it seems that humans still tend to prefer high-fat food when stressed; a study by Zellner and colleagues (2006) found that laboratory-induced acute stress increased women's consumption of high-fat food (i.e., M&Ms) and decreased consumption of low-fat food (i.e., grapes). These food preference effects also extend to non-human animal models, as stress has been shown to selectively increase intake of palatable high-fat/sugar foods in rodents (Dallman et al., 2003; Dallman et al., 2005).

A related area of research has shown that glucocorticoid reactivity to stress subsequently promotes food intake—particularly of high-calorie/fat/sugar foods. In a sample of 59 healthy women, participants who exhibited higher cortisol reactivity to the Trier Social Stress Test consumed more calories and sweet foods that day compared to lower cortisol reactors (Epel,

Lapidus, McEwen, & Brownell, 2001). Furthermore, glucocorticoid-induced preference for sweet substances has been demonstrated in rodents. For example, in adrenalectomized rats unable to naturally produce glucocorticoids, experimental administration of corticosterone has been shown to increase consumption of both saccharin (Bhatnagar et al., 2000) and sucrose (Bell et al., 2001) in a dose-response manner. Therefore, these data indicate that in addition to psychological stress, markers of physiological stress reactivity of the HPA axis also predict and facilitate greater preferences for high-calorie/fat/sugar foods—that is, the same types of foods indicated in unhealthy comfort eating.

How does comfort eating affect health outcomes? In rodent models, there is causal evidence that chronic engagement in comfort eating induces abdominal obesity (Dallman et al., 2005), which is associated with hypertension, type 2 diabetes, and cardiovascular disease (Björntorp, 1990). Similarly, some human studies have observed positive associations between comfort eating and Body Mass Index (Finch & Tomiyama, 2015; Konttinen, Männistö, Sarlio-Lähteenkorva, Silventoinen, & Haukkala, 2010; Ledoux, Watson, Baranowski, Tepper, & Baranowski, 2011; Nolan, Halperin, & Geliebter, 2010). These data are consistent with the Psychosomatic Theory of Obesity, which suggests that some individuals turn to eating to cope with negative affect, chronically leading to overeating and the development of obesity (Kaplan & Kaplan, 1957). Although overall there seem to be more studies documenting a comfort eating-BMI relationship than not, some studies have found comfort eating to be unrelated to BMI (Wardle et al., 1992) and not prospectively predictive of weight gain (Lowe et al., 2006).

Beyond these observed relationships between comfort eating and BMI, the consumption of high-calorie/fat/sugar foods has been linked with a number of negative health outcomes. For example, many unhealthy comfort foods are processed and high in refined carbohydrates, which

are associated with incresed risk of coronary artery disease compared to whole grains (Liu et al., 1999). Furthermore, excessive consumption of dietary sugars has been associated with greater metabolic abnormalities, decreased likelihood of meeting dietary recommendations for essential nutrients, and increased triglyceride levels, which are also a risk factor for coronary artery disease (Johnson et al., 2009). Moreover, in an analysis of approximately 2.4 million deaths in the United States in the year 2000, Mokdad, Marks, Stroup, and Gerberding (2004) identified poor diet as the second leading cause of death.

Concerned that comfort eating might promote negative health outcomes such as these, some researchers have designed interventions to eradicate this behavior (Daubenmier et al., 2011; Katterman et al., 2014). However, comfort eating may be difficult to eliminate because food is accessible and eating is pleasurable. Moreover, it might actually work–accumulating evidence suggests that eating high-calorie/fat/sugar foods can dampen physiological stress responses to both acute and chronic stressors (Tomiyama et al., 2015). Findings from non-human animal studies have demonstrated what Dallman and colleagues (2003) have termed a *chronic stress response network* model—that is, a process through which stress-induced eating reduces neuroendocrine HPA axis activity associated with the physiological stress response. For example, consumption of palatable lard or sucrose has been shown to dampen ACTH secretion in response to chronic restraint stress, compared to a diet of less palatable chow (Pecoraro, Reyes, Gomez, Bhatnagar, & Dallman, 2004). Furthermore, in rats exposed to chronic unpredictable physical stress, daily access to sweetened drinks reduced both hypothalamic CRH mRNA expression and plasma corticosterone (Ulrich-Lai et al., 2007). Foster and colleagues (2009) also found that HPA axis reactivity to acute restraint stress was decreased in rats that had prior access (7 days) to palatable foods versus chow. Evidence from rodent models also suggest

that against a background of chronic stress, comfort eating attenuates HPA responses to acute stress (Dallman et al., 2003).

In addition to dampening physiological stress responses, findings from several rodent studies suggest that palatable food consumption also inhibits behavioral responses to acute and chronic stressors. For example, short-term (7 day) intake of a high-fat diet decreased acute behavioral anxiety in response to an elevated plus maze (Prasad & Prasad, 1996), and a high-fat diet also reduced anxiety and depressive-like behaviors in response to chronic unpredictable social defeat and overcrowding stress (Finger, Dinan, & Cryan, 2011). Another study in rodents found that consumption of a palatable diet decreased anxiety and depressive-like behaviors following chronic maternal separation stress (Maniam & Morris, 2010).

Although these data from non-human animal models seem to consistently suggest that comfort eating acts to dampen stress responses, causal effects of comfort eating on physiological and behavioral stress responses have yet to be to be examined in humans, as no known researchers to date have experimentally manipulated comfort eating behavior and also measured stress, whether psychological or physiological. However, I do note that at least two research groups have experimentally examined the capacity of comfort eating to improve a related, yet different outcome—film-induced negative affect. First, Macht and Mueller (2007) found that chocolate intake improved negative mood to a greater extent than drinking water, and palatable foods also improved mood more than non-palatable foods. In contrast, results from another study revealed that consumption of a favorite comfort food did not improve mood to a greater extent than consumption of a non-comfort food or no food at all (Wagner, Ahlstrom, Vickers, Redden, & Mann, 2014). Therefore, initial causal tests of comfort eating on other psychological outcomes have shown mixed results thus far.

Returning to discussion of stress outcomes in particular, several human studies (Tomiyama, Dallman, & Epel, 2011; Tryon, Carter, Decant, & Laugero, 2013; van Strien, Roelofs, & de Weerth, 2013) have observed correlations between high chronic stress, high emotional eating, and decreased cortisol reactivity to Trier Social Stress Test (TSST)—a gold-standard acute laboratory stressor in which participants perform speech and mental arithmetic tasks in front of a neutral, evaluative audience (Kirschbaum, Pirke, & Hellhammer, 2008). First, Tomiyama, Dallman, and Epel (2011) found that women with high versus low chronic stress reported greater emotional eating, and also showed lower diurnal cortisol levels, greater suppression in response to dexamethasone (a synthetic glucocorticoid) administration, and lower cortisol reactivity to the TSST. This study measured trait emotional using the commonly used and well-validated Dutch Eating Behavior Questionnaire (DEBQ; van Strien, Fritjers, Bergers, & Defares, 1986; van Strien, Herman, & Anschutz, 2012). A second study conducted by van Strien, Roelofs, & de Weerth (2013) also included administration of the DEBQ and TSST, but this study provided the advancement of also assessing post-stress actual eating behavior in the lab. Findings from the study revealed that among women who were high on trait emotional eating, those who showed an attenuated cortisol response to the TSST actually consumed more food in the lab after the TSST compared to those who showed elevated cortisol reactivity. In a third laboratory study with a similar design, women with high chronic stress exhibiting low cortisol reactivity to the TSST consumed significantly more calories from chocolate cake compared to those with low chronic stress and high cortisol reactors (Tryon, DeCant, & Laugero, 2013). In sum, although none of these studies experimentally manipulated eating behavior, they do evidence linkages between high chronic stress, increased comfort eating, and reductions in cortisol reactivity to acute social-evaluative stress in the laboratory.

In addition, at least one human study has tested potential effects of comfort eating on psychological stress. In a sample of 2,379 young adult women, I investigated whether comfort eating behavior might moderate the relationship between adverse life events and psychological stress (Finch & Tomiyama, 2015). Results indeed showed that greater self-reported comfort eating statistically buffered the relationship between adverse life events and perceived stress. However, this effect was not observed among women exhibiting severely elevated levels of depressive symptoms, indicating that perhaps comfort eating is not an effective stress-reduction strategy for this population. Nonetheless, taken together, these studies provide preliminary evidence that comfort eating may also reduce psychophysiological stress responses in humans.

Importantly, the comfort eating literature has not taken advantage of existing theoretical models of emotion regulation, and therefore has yet to gain a comprehensive understanding of *when* comfort eating dampens stress processes. Theoretically, Gross' process model of emotion regulation (2002) posits that negative emotional responses to events are more effectively attenuated by strategies used earlier in the stress process versus later. However, anecdotally comfort eating seems to be a strategy that individuals use after stressors have already occurred. The vast majority of rodent studies have manipulated comfort eating such that it takes place prior to stress (Finger et al., 2011), and have consistently found that this timing of comfort eating is effective in dampening stress responses. Interestingly, however, at least one rodent study found that compared to access to chow, access to a high-calorie/fat diet *after* chronic social defeat stress worsened recovery from stress-induced behavioral deficits such as social avoidance (Chuang et al., 2010). Moreover, the two aforementioned experimental studies in humans (Macht & Mueller, 2007; Wagner et al., 2014) have both tested effects of comfort eating *after* the negative event (film-induced sadness), and have yielded mixed results regarding mood repair.

The only known study to compare the effects of comfort eating before versus after a negative event in a single research design was conducted by Wagner et al. (2014). Results revealed that those who consumed chocolate before the film and those who simply received chocolate before the film as a gift to consume later were each were significantly less upset by the film compared to both those who ate chocolate after the film, and those who consumed no food at all. Therefore, there is preliminary evidence in humans that comfort eating (or simply receiving a comfort food to consume later) before a negative event may be more effective for minimizing negative mood, compared to post-event comfort eating. Further research is needed in both rodents and humans to further examine the effects of the timing of comfort eating on subsequent stress responses.

Considering the growing cross-species literature evidencing stress-dampening, rather than attempting to eliminate comfort eating altogether, I suggest that researchers should seek ways to change *how* individuals engage in comfort eating, with a particular focus on methods for harnessing the benefits of comfort eating without simultaneously promoting weight gain and poor health over time. In the present research, I examine one potential actionable solution—*healthy comfort eating,* defined as eating fruits and vegetables in response to stress.

Healthy Eating as Comforting

Research aiming to directly or indirectly promote fruit and vegetable consumption is well justified from a public health perspective. The 2015-2020 Dietary Guidelines for Americans currently recommend that fruits and vegetables should constitute one-half of meals and snacks. However, the vast majority of Americans are not meeting the dietary recommendations for fruit and vegetable consumption (about 75% and 85%, respectively; United States Department of Health and Human Services, 2015). Fruits and vegetables are universally promoted as healthy,

and for good reason—they are generally both low in calories and nutrient-dense, providing a variety of vitamins, minerals, electrolytes, antioxidants, anti-inflammatory agents, and dietary fiber, which is associated with decreased risk for cardiovascular disease and obesity (Slavin & Lloyd, 2012). Thus, fruit and vegetables contain myriad salutary substances.

Furthermore, there is strong evidence linking greater fruit and vegetable intake to health outcomes. A recent meta-analysis of 16 prospective studies including 833,234 participants found that higher fruit and vegetable intake was significantly associated with a lower risk of all cause mortality and cardiovascular mortality, although no relationship was found for risk of cancer mortality (Wang et al., 2014). Moreover, increasing fruit and vegetable consumption appears to be a fruitful intervention target, as an increase of only one fruit or vegetable per day is enough to generate clinically significant health outcomes. For example, in a meta-analysis of nine prospective studies including 221,080 men and women, the relative risk of coronary heart disease was reduced by 4% for each additional serving of fruits and vegetables per day (Dauchet, Amouyel, Herchberg, & Dallongeville, 2006). Similarly, meta-analytic findings have also indicated an inverse dose-response relationship between fruit and vegetable intake and mortality, such that the risk of all cause mortality was decreased by 6% and 5% for each additional daily serving of fruits and vegetables, respectively (Wang et al., 2014). In addition, reviews of intervention research have shown that increased fruit and vegetable consumption may facilitate weight loss, due to these foods' low fat content and energy density, coupled with high water and dietary fiber content (Ledoux et al., 2011; Rolls, Ello-Martin, & Tohill, 2004). Taken together, these data have informed my decision to define healthy foods as fruits and vegetables for the purposes of the present research, given the clear benefits that these foods confer for health.

Interestingly, some individuals already view healthy foods as comfort foods. In a survey study of 411 Americans, Wansink, Cheney, and Chan (2003) found that comfort foods can range from snack-related foods typically thought to be less healthy (e.g., potato chips) to meal-related foods thought to be more healthy (e.g., vegetables or salads). Furthermore, results from another study by Wansink and colleagues in nearly 1,500 Americans revealed that 52% of women and 41% of men viewed vegetables and salads as comfort foods. Similarly, in a survey study of 277 adults, 35% of participants identified low-calorie foods (primarily fruits and vegetables) when prompted to identify their favorite comfort foods (Dubé, Lebel, & Lu, 2005).

As discussed previously, research has reliably demonstrated that both human and non-human animals tend to specifically increase their consumption of high-calorie/fat/sugar foods when exposed to stress, and furthermore, these high-calorie/fat/sugar foods are known to dampen physiological and behavioral stress responses in rodents. Given that high-calorie/fat/sugar food qualities seem to be implicated in comfort eating processes, and also given that fruits and vegetables are predominantly relatively lower in these contents compared to traditional unhealthy comfort foods, an important question arises: why might healthy foods also comfort?

First, it appears that the physiological stress dampening observed in some rodent studies may be mediated through sugar content. In addition to stimulating opioid release (Adam & Epel, 2007), research has suggested that sugar affects a metabolic-brain-negative feedback pathway, such that sucrose inhibits stress-induced cortisol secretion in humans (Tryon et al., 2015). Fruits make plausible candidate comfort foods, as they contain natural sugars such as glucose and fructose. Furthermore, raw vegetables can also contain levels of sugar comparable to fruits; for example, 1 serving of carrots, red peppers, clementines, and strawberries each contains about 6-7 grams of sugar. In addition, even if stress reduction is not related to the actual sugar

macronutrient content, it might be tied to the hedonic reward of sweet *taste.* As discussed earlier, in a pilot study I conducted, young women rated sweet taste as the third most important food characteristic determining whether they consider various foods to be comfort foods. In addition, a cross-species literature has documented that both primates and rodents exhibit positive facial "liking" expressions (e.g., lip licking, rhythmic tongue protrusions) in response to sweet taste (Berridge, 2009). Moreover, sweet tastes activate what Berridge (2009) has termed "hedonic hotspots" in the brain, which are opioid, endocannabinoid, and GABA-benzodiazepine neurotransmitter systems at limbic system sites capable of increasing "liking" reactions purported to reflect pleasure. Therefore, sugar and sweet taste characteristics of fruits and vegetables represent plausible physiological mechanisms that could drive stress dampening.

Second, healthy comfort eating may provide an avenue for individuals to engage in comfort eating without falling prey to feelings of guilt after eating unhealthy foods. Scholars have suggested that some individuals may exhibit a biphasic emotional response to consumption of high-calorie/fat/sugar foods, with initial and temporary feelings of emotional relief, followed by post-consumption feelings of guilt (Bennett, Greene, & Schwartz-Barcott, 2013). Food-related guilt is a common experience; for example, daily diary data in 77 women revealed that approximately two-thirds of women felt guilty about food at least once per week, and among those who reported feeling guilty, about 17% of all weekly eating events were accompanied by feelings of guilt (Steenhuis, 2009). Regarding individual differences in post-consumption guilt, some studies have found that women may be more likely than men to feel guilty after unhealthy comfort eating (Bennett et al., 2013; Dubé et al., 2005).

Importantly, feelings of guilt post-comfort eating appear to depend upon the type of food consumed. In a questionnaire study, Dubé, Lebel, and Lu (2005) found that intensity of guilt

after comfort eating was the highest after consumption of high-calorie sweet foods (e.g., chocolate and ice cream), followed by high-calorie non-sweet foods (e.g., pasta, pizza, and salted snacks), and low-calorie foods (e.g., fruits and vegetables). Consistent with these data, Steenhuis (2009) found that guilt related to candy and ice cream consumption made up 23% of all guilty food events over the course of a week, whereas guilt related to fruits and vegetables each made up only 1.2% of weekly guilty food events. Similarly, additional research in 79 women suggests that guilt is highest after consuming foods perceived to be poor in nutritional value and high in calories or fat (Gonzalez & Vitousek, 2004). Notably, these are the precise characteristics that typically define foods traditionally thought of as comfort foods.

In addition to minimizing post-comfort eating guilt, healthy comfort eating may also protect against increases in other negative emotions and physical symptoms following unhealthy eating, as demonstrated by a snacking intervention conducted by Smith and Rogers (2014). In this experiment, men and women were randomly assigned to consume a daily snack of either fresh whole fruit (i.e., apples, bananas, and clementines) or chocolate/crisps for 10 days. Comparing within-group scores from pre-post intervention, those who ate chocolate/crisps showed significant increases in self-reported depressive symptoms, emotional distress, and fatigue (percentage changes of 47, 10, and 11%, respectively). Comparing post-intervention scores between groups, those in the fruit versus the chocolate/crisps condition showed significantly lower anxiety, depressive symptoms, and emotional distress, as well as lower somatic symptoms, cognitive difficulties, and fatigue. However, at least one study has found that consumption of unhealthy foods does not necessarily induce negative emotion (Wagner et al., 2014). Wagner and colleagues conducted an experiment to investigate whether film-induced negative affect would be improved to a greater extent by consumption one's favorite comfort

food (e.g., chocolate, ice cream, and cookies), one's equally-liked non-comfort food (e.g., almonds, cashews, and popcorn), a neutral food (i.e., granola bars), or no food at all. Results revealed that negative mood improved over time to the same extent regardless of condition. However, changes in mood were assessed for a relatively short time period of only 3 minutes in this study, ranging from immediately pre- to post-food consumption. Thus, it is possible that this brief assessment window may not have extended far enough past the time of consumption to capture potential biphasic changes in emotion resulting from unhealthy comfort eating.

Next, I discuss a third reason why healthy foods make good candidate comfort foods: perhaps stress-dampening effects of comfort eating may be driven in part by *learned associations* between comfort foods and experiences of reduced stress. Although the aforementioned studies showing that rodents tend to eat more high-calorie/fat/sugar foods when stressed seem to suggest that comfort eating is an unlearned behavior, other evidence also indicates that food preferences—both in general and for high-calorie/fat/sugar foods—may be at least somewhat learned and influenced by environmental factors. First considering general food preferences, Van de Waal, Borgeaud, and Whiten (2013) found that when infant monkeys were presented with several novel foods, they first ate the food they had seen their mothers eat, suggesting that food preferences are socially learned. Further research by this group observed that male monkeys who immigrated to a new group subsequently abandoned food preferences from their home group and adopted the food preferences of the new group, even when no higher ranking monkeys from the new group were present during eating. Regarding food preferences for unhealthy foods, Osman and Sobal (2006) found that although 90% of Spanish women and 78% Spanish men reported chocolate cravings, this gender difference was no longer significant after controlling for Spanish cultural environment, indicating that preferences for highly palatable

foods are influenced by culture. In addition, whereas Americans have been shown to hold implicit associations between unhealthy foods and tastiness, in France, unhealthy foods are implicitly linked with bad taste, while healthy foods are associated with tastiness (Werle, Trendel, & Ardito, 2013). Taken together, these studies suggest that sociocultural or other environmental factors play a role in the natural development of food preferences, which opens the door for conditioning individuals to form new associations with healthy foods.

Although no known experimental studies have applied associative learning methods to pair healthy foods with stress reduction, many studies have paired healthy foods with other positively valenced stimuli to shape perceptions and choice of healthy foods. Given that eating habits learned in childhood can persist into adulthood, much of this work has been done in child or adolescent samples (Wadhera, Phillips, & Wilkie, 2015). For example, both children and adults show increased desire to eat initially disliked foods after they have viewed photos of others making pleasant faces with the foods, versus viewing photos the foods alone (Barthomeuf, Droit-Volet, & Rousset, 2012). As reviewed by Wadhera and colleagues (2015), in samples of both human and non-human animals, many studies have achieved increased preference for initially neutral or novel foods by repeatedly pairing them with either a high-calorie substance—a paradigm known as flavor-calorie learning—or an already highly preferred flavor—that is, flavor-flavor learning. Other research has examined an associative conditioning procedure called flavor-context learning, wherein a neutral or novel food is repeatedly paired with the emotional valence of the social context. For example, Birch, Zimmerman, and Hind (1980) found that pairing food with positive caregiver attention promoted children's liking of the food.

Importantly, associative learning techniques such as these have already proven effective for specifically improving liking and preference for healthy foods such as vegetables (Anzman-

Frasca, Savage, Marini, Fisher, & Birch, 2012; Barthomeuf et al., 2012; Birch et al., 1980). To build upon this literature, Study 2 attempted to promote healthy eating in a novel way: by experimentally pairing fruits with *stress reduction* using associative conditioning.

How common are existing lay-associations between comfort foods and stress reduction? To begin answering this question, I conducted an initial pilot survey in 402 undergraduate women assessing their expectations about whether healthy and unhealthy foods improve mood. Participants rated one of their favorite fruits or vegetables, and one of their favorite processed, high-calorie/fat/sugar foods on, "*How confident are you that eating that food would make you feel better if you were in a bad mood?*" (1 = *not at all confident* to 7 = *very confident).* Participants gave an overall rating of 4.12 (*SD* = 1.68) for healthy foods, and 4.31 (*SD* = 1.69) for unhealthy foods. Although healthy foods were rated significantly lower ($p < .001$), the absolute difference between these means is small (0.19 on a 1-7 scale), and these data suggest that some individuals do indeed already associate healthy food with mood improvement.

Pavlovian Conditioning: Background and Application to Healthy Comfort Eating

The particular type of associative learning utilized in the aforementioned studies of food preference is called Pavlovian conditioning. Pavlovian conditioning—also known as classical conditioning—has traditionally been conceptualized as a process in which an organism learns an association between an initially neutral stimulus and a stimulus that elicits a reflexive response prior to the learning, an unconditional stimulus. After these two stimuli have been repeatedly paired together, presentation of the formerly neutral stimulus alone will elicit a reflexive response. To demonstrate a common Pavlovian conditioning procedure, consider the following example of research conducted by Pavlov himself (1927). Pavlov noticed that meat powder (an unconditional stimulus; US) caused dogs to salivate (an unconditional response; UR) without any

prior training with meat powder exposure. He then exposed the dogs to the repeated pairing of the meat powder with the sound of a bell (a conditional stimulus; CS), and soon found that after several pairings, exposure to the bell tone alone caused the dogs to salivate (a conditional response; CR). The bell tone served as a conditional stimulus, because it was initially a neutral stimulus to the dogs, and did not come to elicit salivation until it had previously been paired with the meat powder.

Applying this Pavlovian conditioning model to the context of healthy comfort eating, Study 2 of the proposed research will repeatedly pair a healthy, raw fruit (CS) with stress reduction (US), which is known to elicit decreased signs of psychophysiological stress (UR). I expect that this pairing will subsequently cause the healthy fruit alone to elicit reduced signs of psychophysiological stress (CR). I expected that this pairing would subsequently cause the healthy fruit alone to reduce psychophysiological stress (CR). Table 1 presents a comparison of stimuli and responses used in Pavlov's classic research in dogs, versus those used in Study 2.

Table 1

Stimuli and Responses in Pavlov (1927) versus Study 2

	Pavlov (1927)	**Study 2**
Unconditional stimulus (US)	Meat powder	Stress reduction
Unconditional response (UR)	Salivation	Decreased psychophysiological stress
Conditional stimulus (CS)	Bell tone	Fruit
Conditional response (CR)	Salivation	Decreased psychophysiological stress

In order to reliably induce stress reduction for Pavlovian conditioning trails in Study 2, participants engaged in a stress reduction activity known as Progressive Muscle Relaxation (PMR). A well-established body of literature evidences that a brief Progressive Muscle Relaxation activity decreases perceived stress and anxiety (see Carlson & Hoyle, 1993 for a meta-analysis), as well as reduces heart rate, blood pressure, muscle tension, respiration rate, and

skin conductance (see King, 1980 for a review). This supporting literature informed my decision to utilize PMR as a method for inducing the US—that is, stress reduction.

To provide the context for Study 2, I next provide a brief review of relevant background information regarding Pavlovian conditioning. Here, I review a number of methodological factors known to influence conditional responding, going on to discuss how I expected that these factors would play a role in Study 2.

Control group. To determine whether an observed CR is uniquely due to temporal CS-US pairing, researchers must choose an appropriate control group. As reviewed by Rescorla (2012), many of the conventional control groups typically used in Pavlovian conditioning studies are limited and inadequate for making such a determination. For example, in *CS-alone control*, control participants receive the same amount of CS presentations as experimental participants, but do not receive US presentation. Similarly, in a *US-alone control*, control participants receive the same amount of US presentations as the intervention group, but do not receive CS presentation. However, both of these control procedures are limited, as any observed response differences could be explained by differences in exposure to the stimulus that the control group did not receive, rather than CS-US pairing. A comparatively improved control procedure is the *explicitly unpaired control*, wherein control participants receive the same number of CS and US presentations as the intervention group, except the CS and US are ensured to never occur in close temporal proximity. As noted by Rescorla (2012), this procedure achieves an equivalent number of CS and US presentations, and participants learn that the US will *not* follow the CS. I utilized an explicitly unpaired control in Study 2, such that those in the control group were exposed to the fruit and stress reduction the same number of times as the intervention group throughout the

intervention; however, these stimuli never occurred with temporal overlap in the control group, whereas they always occurred with temporal overlap in the intervention group.

Stimulus salience. Another important factor affecting the strength of a CR is the salience, or noticeability of a given stimulus (McLaren & Mackintosh, 2000). Researchers can increase the salience of a CS by choosing a CS form that is similar to actual stimuli than an organism might encounter in its natural environment (Cusato & Domjan, 2000). For example, a study investigating maternal attachment behavior in rhesus monkeys might choose a cloth-covered surrogate mother as a CS, rather than a less naturalistic and arbitrary bare-wire surrogate mother (Harlow, 1958). Study 2 applied this technique by providing participants with the fruit CS in its raw, whole form, which is more easily recognizable than fruit that is processed in some way (e.g., fruit in a smoothie). In addition, one can make a US more salient by increasing its intensity, or by making it more relevant to the physiological needs of the organism. For example, studies have shown that appetitive behavior for (Krieckhaus & Wolf, 1968), or aversion to (Sawa, Nakajima, & Imada, 1999) salt can be more efficiently induced in salt-deficient rodents than non-deficient controls. Applying this factor to Study 2, I increased the salience of the fruit CS and made it more relevant to the biological needs of the participants by instructing them to abstain from eating in the 3 hours prior to fruit consumption for each trial.

Context. Conditioning trials do not take place in a vacuum; instead, they each occur in a certain setting or context. Contexts are complex and comprised of many features, and if the context of repeated trials is not varied, aspects of the context itself can come to represent additional conditional stimuli associated with the US. For example, in a phenomenon known as *overshadowing*, if two given conditional stimuli are present during a trial, the CS that is more salient or intense may overshadow, or interfere with conditional responding to the other, less-

salient CS (Jennings, Bonardi, & Kirkpatrick, 2007; Pavlov, 1927). This is an example of *cue competition*, a phenomenon wherein conditional stimuli that are presented together are thought to compete for associative linkage to a common US (Savastano & Miller, 1998).

Context-specific conditional stimuli can also function as modulators signaling to the organism that the nature of the original CS-US binary relation is dependent upon which contextual cues are present (Thomas, McKelvie, & Mah, 1985). To actively minimize these complications and optimize learning related to eating behavior, Study 2 followed the recommendation of Boutelle and Bouton (2015) to conduct trials in multiple, varied contexts, thus increasing the number of contexts wherein the fruit-stress reduction association is learned. In addition, these scholars have advocated conducting trials in the contexts that are more problematic; for example, a researcher aiming to discourage overeating using extinction conditioning might conduct trials in contexts in which food cues are most abundant, such as in one's kitchen, dining room, or favorite restaurant; or during certain times of day or mood-states. Similarly, Study 2 advised participants to complete trials in contexts where they may be exposed to, or tempted to eat unhealthy food, such as in campus dining halls, or while experiencing stress or other negative emotions.

CS-US Relevance. The rate of learning also depends upon the extent to which the CS is relevant to, or "goes with" the US (Rescorla, 2008). For example, Öhman and Dimberg (1978) demonstrated that learned associations between CS facial expressions and aversive shock were more resistant to extinction when the face was angry, whereas extinction occurred immediately after the shock was withheld for neutral or happy faces, which are seemingly more discordant with aversive shock. Similarly, Öhman and Mineka (2001) found that fear conditioning

progressed more quickly when stimuli that were dangerous in evolutionary history (e.g., snakes) served as conditional stimuli, compared to fear-irrelevant, neutral stimuli (e.g., flowers).

For participants in the experimental condition in Study 2, I noted that CS-US relevance could have been an important factor, as other potential conditional stimuli in the context might "go with" the stress reduction (US) more than the fruit. For example, I speculated that the soothing sounds of the narrator's voice in the PMR recording may be intuitively more relevant to stress reduction than the fruit. This could have posed a problem wherein participants might more readily learn an association between the soothing voice and stress reduction, rather than the fruit and stress reduction. That is, the soothing vocals could engage in cue competition with the fruit, and the vocals could overshadow learning about the fruit. To avoid this scenario, participants were pre-exposed to the PMR recording in online pre-screening, prior to their first conditioning trials paring fruit with stress reduction. In this way, when the experimental trials actually begin, participants will ostensibly pay less attention to the soothing vocals, and more attention to the newly added fruit paired with the US, thus increasing the salience of the fruit and boosting the magnitude of learning about fruit-stress reduction learning.

Stimulus novelty. In a phenomenon called the CS pre-exposure effect (also known as latent inhibition), if an organism has previously encountered a CS alone prior to conditioning, a greater number of conditioning trials are required to form a CR than if the organism has not previously been exposed to the CS (Hall & Pearce, 1979). Scholars have suggested that this may be because prior CS exposure decreases attention to the CS, thereby disrupting later learning about the stimulus (Lubow & Gewirtz, 1995). Stimulus novelty can also be an important US characteristic affecting the CR. Prior research has revealed a US pre-exposure effect, wherein conditional responding is slower to develop if participants have been previously exposed to the

US alone prior to pairing with the CS (Randich & LoLordo, 1979; Saladin, Ten Have, Saper, Labinsky, & Tait, 1989). However, at least some evidence in non-human animals has suggested that only 1 US pre-exposure is not sufficient to hinder learning, and even 5 US pre-exposures may have a rather small effect on the progress of learning (Saladin et al., 1989).

Furthermore, there is considerable evidence that CS (Bouton, 1993; Revillo et al., 2014) and US (Wasserman & Miller, 1997) pre-exposure effects are context dependent, meaning that they can be avoided by changing the context between the pre-exposure and conditioning phases of the procedure. I applied this notion of context dependent US pre-exposure to Study 2. As noted above, the first time that participants encountered the PMR activity (the US), the context was outside of the lab, via online pre-screening. Then, the first time that participants actually completed an experimental trial pairing fruit with stress reduction, the context was different, as this first CS-US pairing to take place in the laboratory setting. Therefore, I expected that my use of a US pre-exposure would not slow associative learning, due to alterations in context.

Number of trials. With an increasing number of trials, the strength of CS-US associations is known to steadily increase to an asymptotic value (Havermans & Jansen, 2007). However, as noted by Fanselow and Wassum (2016), traditional definitions of Pavlovian conditioning are mistaken in their assertion that learned conditional responding *requires* repeated US-CS pairings. In some conditioning models, organisms can learn a CR after only one trial. For example, in a taste aversion paradigm, an organism can learn to avoid consuming a given food after only one instance of getting sick after consuming that food (Swank & Bernstein, 1994). Although this single-trial learning has also been observed in fear-conditioning paradigms (Schafe & LeDoux, 2000), it is typically only effective in studies with very aversive stimuli and is rarely achieved in some other appetitive forms of conditioning (e.g., salivary conditioning; Pavlov,

1927). Thus, since Study 2 is outside of the context of taste aversion or fear conditioning, I utilized multiple conditioning trials. To provide a conservative test of Pavlovian conditioning on the desired outcomes, I utilized the upper realistic trial number bound from the perspective of participant burden and adherence. As the majority of the trials were self-administered by participants outside of the laboratory, I chose 7 trials as the upper feasible limit. This decision is supported by an online mindfulness intervention study conducted by Davis and Zautra (2013) which also instructed participants to complete 15-minute online exercises with an audiotape component, but found that participants only completed about 8 of the 12 exercises on average.

Stimulus generalization. In a phenomenon known as *stimulus generalization*, after Pavlovian conditioning trials with a given CS-US pairing, an organism can show generalized learning, in that it may also show a conditional response to a second CS (CS2) that is similar in some way to CS1, but not the same exact CS used in the conditioning trials (Pavlov, 1927). In their review of a century of research on stimulus generalization, Ghirlanda and Enquist (2003) concluded that stimulus generalization is a universal phenomenon that robustly persists across species (i.e., human and various non-human animals), behavioral contexts (e.g., feeding, drinking, courting), and sensory modalities (e.g., light, sound). Study 2 tested for stimulus generalization effects in the following way: although participants performed conditioning trials with only one specific fruit (CS1), the final test of conditional responding also included foods (CS2s) that are distinct from the CS1, but also share a property with the CS1 (i.e., they are classified as fruits). I decided that if participants in the experimental versus control group consumed more of these fruits that were not specifically included in prior conditioning trials, that I would interpret this effect as stimulus generalization.

In sum, although an exhaustive review of decades of Pavlovian conditioning research was beyond the scope of this review, the previous discussion of relevant factors known to impact conditional responding was intended to provide methodological background information for Study 2, which utilized Pavlovian conditioning in the context of healthy comfort eating.

Conclusion

Here, I reviewed the evidence that consumption of high-calorie/fat/sugar foods dampens both behavioral and physiological stress responses, and went on to suggest that healthy foods—defined as fruits and vegetables—may also serve as comfort foods and alleviate stress. After identifying learned associations between food and stress reduction as a primary mechanism through which foods might comfort, I proposed the application of Pavlovian conditioning methodology to forge such associations, using healthy foods as conditional stimuli. In sum, I suggest that investigating healthy foods as comfort foods holds three key areas of promise for improving health and well-being: (1) if healthy foods do indeed comfort, this provides many chronically stressed individuals with a potentially new stress-reduction technique; (2) the proposed benefits of healthy foods for stress reduction may provide individuals with added motivation to consume fruits and vegetables, consequently improving their likelihood of meeting the dietary recommendations for these foods; and (3) over time, healthy comfort eating may have salutary effects on morbidity and mortality.

Study 1: Consequences of Healthy Comfort Eating

Aims and Hypotheses

Using a randomized, controlled experimental design manipulating comfort eating in the context of a validated laboratory stressor, Study 1 pursued the following aims:

Aim 1: Assess whether consuming healthy foods reduces psychological stress processes to the same extent as unhealthy foods.

Hypotheses: Both healthy foods (fruits and vegetables) and unhealthy (processed, high-calorie/fat/sugar) foods will reduce psychological stress reactivity, compared to a non-food control. In addition, both healthy and unhealthy foods will enhance psychological stress recovery, compared to a non-food control.

Aim 2: Evaluate whether consuming healthy foods reduces physiological stress to the same extent as unhealthy foods.

Hypotheses: Both healthy and unhealthy foods will dampen physiological stress reactivity of the HPA axis (indexed by cortisol levels) and SNS (indexed by pre-ejection period), compared to a non-food control. In parallel, the control group will show greater decreases in parasympathetic nervous system (PNS) activation (indexed by heart rate variability) during the stress reactivity phase, compared to the healthy and unhealthy food conditions. Similarly, both healthy and unhealthy foods will enhance physiological stress recovery of the HPA axis, SNS, and PNS, compared to a non-food control.

Aim 3: Test whether the timing of comfort eating—that is, eating before versus after a stressful event—differentially affects psychophysiological stress recovery.

Hypotheses: Comfort eating before versus after the TSST will enhance psychophysiological stress recovery.

Aim 4: Determine whether any observed effects of healthy or unhealthy comfort eating on psychophysiological stress reduction are moderated or mediated by plausible psychological factors or food macronutrient content.

Hypotheses: Stress buffering effects will be greater in those individuals who: (1) express greater expectations that eating will improve mood, (2) exhibit higher scores on trait emotional eating, (3) report higher chronic stress levels, (4) report lower feelings of guilt after food consumption in the lab, and (5) consume a greater amount of sugar from food in the lab.

Method

Note

Prior to conducting any data analysis, all a priori hypotheses were pre-registered online via the Open Science Framework at: https://osf.io/j95tf/wiki/home/.

Study Design

In the context of an acute laboratory stressor (the TSST), participants were randomly assigned to one of five experimental conditions according to a 2 (eating healthy vs. unhealthy food) x 2 (eating before vs. after the TSST) + 1 (non-food control) design.

Participants

Participants were 150 undergraduate women (n = 30 per condition) who participated for research credit in their psychology courses. For power analysis, I used G*Power software to estimate the necessary sample size to detect an interaction effect for a between-subjects factor (5 conditions of the experimental eating manipulation) and a within-subjects factor (time, across 4 time points from baseline to 60 minutes post-TSST) on cortisol response to the TSST.

As shown in Table 2, I estimated the sample size required for several scenarios, specifying various desired power levels (i.e., .80, .85, and .90), estimates of repeated measures correlation between pre-post food ratings (i.e., r = .5, .6, and .7), and estimates of the interaction effect between condition and time. For the latter, I specified conventional values (Bakeman, 2005) for a small effect size of $\boldsymbol{\eta_p^2}$ = .02, and a medium effect size of $\boldsymbol{\eta_p^2}$= .06. A sample size of

150 participants (n = 30 per condition) provides power of over .90 to detect a within-between interaction of condition and time on cortisol secretion, even if the interaction effect size is small ($\eta_p^2 = .02$) and there is a .5 correlation between cortisol measurements across the TSST.

Table 2

Study 1 Sample Size Calculation

	Repeated measures correlation (r)					
	.50		.60		.70	
	Interaction partial eta squared (η_p^2)					
	.02	.06	.02	.06	.02	.06
Power						
.90	140	50	115	40	85	30
.85	125	45	100	35	75	30
.80	110	40	90	35	70	25

Procedures

Recruitment and pre-screening. The university IRB committee approved all study activities. Participants were recruited via an online advertisement of the study on the university psychology subject pool portal. Interested individuals contacted the experimenter via email, and staff then provided a link to online pre-screening questionnaires. In this pre-screening, potential participants provided information about their demographic information and health status, which determined eligibility. Further details about pre-screening questionnaires are provided below.

Inclusion criteria included: female, aged 18 or older, and fluent in English. I chose to exclusively recruit women for this study, as prior research has indicated that a greater proportion of women than men report engaging in comfort eating (American Psychological Association, 2012; Greeno & Wing, 1994; Zellner et al., 2006). Exclusion criteria were chosen based on incompatibility with the study methods or with cortisol measurement, and included: metabolic or endocrine disease, post-menopausal status, chronic asthma, history of substance abuse or eating disorder, current strict dieting, or current major psychiatric illness (see Appendix A for these pre-questionnaire items). I also excluded individuals exhibiting an elevated level of depressive symptoms (score > 23 on the Center for Epidemiological Studies Depression Scale; Radloff,

1977), as my previous research has offered preliminary evidence that comfort eating may not dampen psychological stress in this population of young women (Finch & Tomiyama, 2015).

Also in pre-screening, individuals completed a Food Opinions Survey adapted from Wagner and colleagues (2014). This survey presented a list of 10 healthy foods—defined as fruits and vegetables—and asked individuals to rank their top three foods from this list in response to the prompt, "What foods would make you feel better if you were in a bad mood?" Similarly, individuals were presented with a list of 10 unhealthy foods (i.e., high-sugar/high-fat, processed, non-whole foods) and asked to rank their top three foods from this list in response to the same prompt. All 20 foods are shown in Table 3. These questions were embedded in a series of distractor questions, in which individuals are also asked to rate their top three choices from each food list for prompts such as, "What foods would you want if you were on-the-go?" and "What foods would you want if you were watching a movie?" I selected these lists of 10 healthy and unhealthy foods (shown in Table 3) based on which foods were rated most highly in a pilot survey in 73 undergraduate women, wherein participants rated 112 healthy and unhealthy foods and beverages on "To what extent would this food/beverage make you feel better if you were in a bad mood?" (1 = *not at all* to 7 = *very much*). Compared to the 10 selected unhealthy foods, the 10 healthy foods contain on average about 163 fewer calories, 9.9 fewer grams of fat, and 6.4 fewer grams of sugar.

Table 3

Study 1 Healthy and Unhealthy Foods

Healthy Food	**Unhealthy Foods**
Apple	Brownie
Banana	Cheesecake
Bell pepper	Cheetos
Carrots	Chips
Celery	Chocolate
Clementines	Chocolate chip cookies
Cucumber	Cupcake
Grapes	Ice cream
Orange	Mac n' cheese
Strawberries	Pizza

Lab day procedure. Figure 1 presents a timeline of the lab day activities. For the

duration of the lab visit, participants were attached to wireless physiological Biopac equipment (Goleta, CA) using electrocardiography and impedance cardiography with non-invasive sensors to assess measures of ANS activation, including electrodermal activation,[1] heart rate variability, and pre-ejection period. All ANS measures were collected continuously throughout the duration of the lab visit. Participants were told to sit with their legs and ankles uncrossed with their feet flat on the floor to avoid postural influences on ANS data collection. Before baseline ANS measurements were taken, participants were given 3 minutes to sit and relax to become accustomed to the sensation of having physiological equipment on the body. Then, baseline ANS measures were recorded for 5 minutes and participants completed the PANAS mood questionnaire for the first time, followed by collection of the baseline salivary cortisol sample.

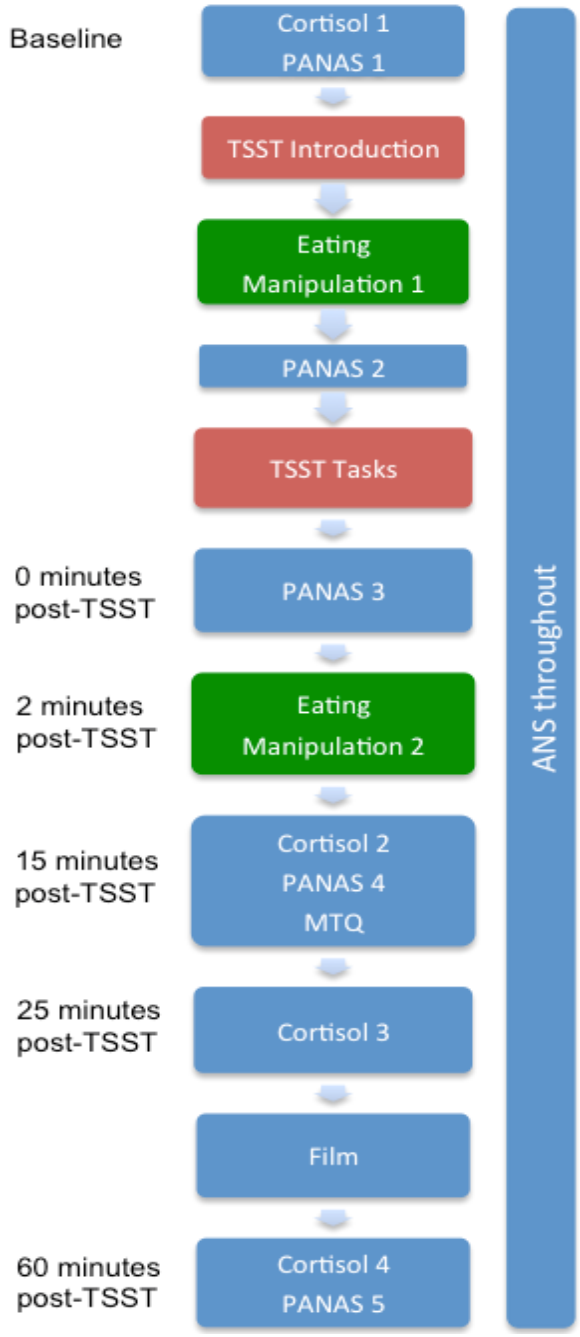


Figure 1. Study 1 lab day activities timelines

Then, three members of research staff

[1] Electrodermal activation was measured via two non-invasive electrodes placed on the fingers; however, the transmitted signals for this outcome were too noisy to be analyzed, most likely because the simultaneous assessment of impedance can interfere with electrodermal activation signal transmission.

dressed in white lab coats entered the room, and informed participants that they would soon be delivering a 5-minute speech to be evaluated by a trained committee. After these TSST staff left the room, participants randomly assigned to conditions 1 and 2 were provided with two servings (each serving in its own dish) of their top-rated unhealthy or healthy comfort food, respectively. These participants were then told to consume at least one dish of the food (i.e., one serving) in the next 5 minutes. Alternatively, participants in conditions 3, 4, and 5 were not given food at this time, and were instead told to simply sit and wait for 5 minutes while the staff member prepared the next part of the study. All participants were left alone in the room for this 5-minute period.

Next, all participants completed the PANAS for the second time, and were given 3 minutes to prepare for their speech. The TSST staff then returned to the room and two TSST staff members administered the 5-minute speech task, followed by a 5-minute mental arithmetic task. Both tasks were video and audio recorded using Photo Booth software for Mac. Following standard protocol, the TSST staff maintained a neutral, unresponsive demeanor and did not provide any positive feedback or facial expressions. The TSST is known to reliably induce cortisol responses (Kudielka, Hellhammer, & Kirschbaum, 2007).

Immediately after the TSST, participants completed the PANAS a third time. Then, participants randomly assigned to conditions 3 and 4 were provided with two servings (each serving in its own dish) of their top-rated unhealthy or healthy comfort food, respectively. These participants were then told to consume at least one dish of the food (i.e., one serving) in the next 5 minutes. Alternatively, participants in conditions 1, 2, and 5 were not given food at this time, and were instead told to simply sit and wait for 5 minutes while the staff member prepared the next part of the study. All participants were left alone in the room for this 5-minute period.

It is noted that those participants randomly assigned to condition 5 did not consume food at any point during the lab visit, whereas participants in all other conditions consumed food either before the TSST tasks (conditions 1 and 2), or after the TSST tasks (conditions 3 and 4). I chose to provide participants with their top-ranked foods in order to enhance ecological validity of the eating manipulations. In addition, the fruits and vegetables in the healthy food conditions were served raw (i.e., not cooked) and prepared in bite-size pieces when appropriate (e.g., apples were sliced, and chocolate was broken into pieces). Unbeknownst to participants, the experimenter weighed each dish of food both before and after the eating manipulations, and staff also recorded the calorie, fat, and sugar content of each food.

After the second eating manipulation, all participants completed the PANAS a fourth time, as well as a Post-Stressor Appraisals scale, and a single-item hunger assessment. Then, participants were told to simply sit and rest for 3 minutes in order for resting physiology signals to be taken, although the true intended purpose for this wait time was to provide participants with a chance to ruminate, as the following assessment was completion of the Modified Thoughts Questionnaire (MTQ), which included a negative thoughts rumination measure.

Next, the second cortisol sample was collected at 15 minutes post-TSST, followed by administration of the Perceived Stress Scale, and several other surveys assessing constructs outside of the scope of the present research (e.g., beliefs about the effects of alcohol). At 25 minutes post-TSST, the third cortisol sample was collected. Then, for the remainder of the stress recovery period, all participants viewed a film with neutral emotional valence—a detailed explanation of how products such as hearing aids and toilets are manufactured. At 60 minutes post-TSST, final PANAS and cortisol assessments were administered. The experimenter then detached all physiology equipment and measured participants' weight and height.

At the conclusion of the lab visit, the experimenter conducted a brief structured interview with participants to ask them what they thought the purpose of the study was, and if there were any procedures that seemed suspicious. Finally, participants were debriefed regarding the true purpose of the study, and were informed that the TSST committee members were trained to behave in a neutral and standardized way during the speech and math tasks.

Measures

Pre-questionnaire measures. Appendix A contains a complete list of items from Study 1 pre-questionnaire measures.

***Demographic information*.** Participants self-reported various demographic characteristics. The following variables were included to determine eligibility, as described above: age, gender, fluency in English, history of eating disorder or substance abuse, dieting status, metabolic or endocrine disease, current major illness or injury, current diagnosed psychiatric condition, post-menopausal status. The following variables were included to characterize the sample: racial/ethnic heritage, weight, height, perceived weight, family income while growing up, and subjective social status as assessed via the MacArthur Scale of Subjective Social Status-Youth Version (Goodman et al., 2001).

***Depressive symptoms*.** Depressive symptoms were assessed using the Center for Epidemiological Studies Depression Scale (CES-D Scale; Radloff, 1977). Participants completed 20 self-report items to rate how often they had experienced various feelings or behaviors in the past week using a 4-point scale (0 = *rarely or none of the time* and 3 = *most or all of the time*). Sample items include: "I felt that people disliked me," "My sleep was restless," and "I had trouble keeping my mind on what I was doing." Positively framed items were reverse coded and all items were summed to calculate a total CES-D score, with higher scores indicating greater

levels of depressive symptoms. Consistent with published studies using the CES-D in samples of young adult women (Finch & Tomiyama, 2015; Franko et al., 2004), I used a conservatively high cutoff score of 24 or higher to define an elevated level of depressive symptoms.

***Food opinions*.** The Food Opinions Survey (Wagner et al., 2014) used in pre-screening was described in detail above.

***Trait emotional eating*.** Trait-like emotional eating was measured via self-report using the 13-item Emotional Eating Subscale from the Dutch Eating Behavior Questionnaire (van Strien, Fritjers, Bergers, & Defares, 1986), which has demonstrated good psychometric properties (van Strien, Peter Herman, & Anschutz, 2012). This subscale prompts participants to rate how often they have a desire to eat when experiencing 13 different emotions (e.g., lonely, worried, disappointed) from 1 = *never* to 5 = *very often*. All 13 items were averaged to create mean scores, with higher scores indicating higher trait emotional eating.

Lab Day Questionnaire Measures. Appendix B contains a complete list of items from the following questionnaire measures administered on lab day.

Chronic perceived stress. The 14-item Perceived Stress Scale (PSS) was administered as a measure of chronic perceived stress in the past month (Cohen, Kamarck, & Mermelstein, 1983). Sample items include: "In the last month, how often have you were unable to control the important things in your life?" and "How often have you found that you could not cope with all the things that you had to do?" on a 5-point Likert scale (1 = *never* and 5 = *very often).* Positively framed items were reverse coded and all item responses were summed to create a total PSS score, with higher scores indicating greater chronic perceived stress. The PSS has demonstrated good psychometric properties; in nationally representative samples, the inter-item reliability of the PSS ranges from a Cronbach's alpha of .78 to .91 (Cohen & Janicki-Deverts, 2012).

Hunger. Hunger was assessed with the item, "How hungry are you feeling right now?" from 1 = *not at all* to 7 = *extremely hungry*.

Mood. Positive and negative mood were assessed at five time points (see Figure 2) using the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The scale includes 20 emotion items from the original scale, with the addition of the two items "sad" and "happy" included in their relevant subscales. Example item: "Indicate to what extent you currently feel this way," for the item "excited," on a scale from 1 (*very slightly or not at all)* to 5 (*extremely*). I assessed mood reactivity to the TSST by examining change in positive and negative mood (in separate models) from baseline through the anticipatory stress period (PANAS 2) and immediately post-TSST (PANAS 3). I examined mood recovery as change in positive and negative mood (in separate models) from immediately post-TSST (PANAS 3) through 15 and 60 minutes post-TSST (PANAS 4 and 5, respectively).

For analyses testing guilt as a mediator of stress-buffering effects (see Aim 5), the guilt item from the PANAS was used in analysis, and the PANAS time point that followed the relevant food manipulation was used (refer back to Figure 1 to view the study timeline). That is, the guilt item from PANAS 2 was used for reactivity mediation analyses, and the guilt item from PANAS 4 was used for recovery mediation analyses.

Post-stressor appraisals. I created this 7-item visual analog series scale to assess participants' appraisals of the TSST. Sample items include, "I felt that the tasks were stressful" and "I was mentally and emotionally prepared for the tasks." Item responses were summed to create a total score (with the positively-framed items reverse coded), such that higher scores indicate greater perceived stress. The scale's reliability was high (Cronbach's alpha = .848).

Rumination. Post-TSST rumination was measured using The Negative Thoughts

Subscale from the Modified Thoughts Questionnaire (Zoccola, Dickerson, & Zaldivar, 2008), which consists of 14 items assessing how much participants had certain negative thoughts in the time since the speech task had ended. Sample items include, "How often did you think about how bad your speech was?" and "How often did you think that you must have looked stupid?" on a 5-point scale (*never* to *very often*). Item responses were summed to create a total Negative Thoughts Subscale score, such that higher scores indicate greater negative thought rumination.

Comfort eating expectations. In collaboration with colleagues Jeff Hunger and Janet Tomiyama, I created a 6-item Comfort Eating Expectations Scale to assess the extent to which participants believe that food improves their mood. Example item: "At the end of a stressful day, I can count on my favorite food to help me relax", and "Eating a good meal when I'm down always puts me in a better mood" (1 = *not true at all* and 6 = *extremely true*). Negatively-framed items were reverse coded and all item responses were averaged to create a mean score, such that higher scores indicate greater participant expectations that comfort eating will improve mood. The final version of the scale was refined by removing the item "When I feel anxious, even my favorite comfort foods do not make me feel better," as the scale's reliability improved when this item was deleted (change from Cronbach's alpha = .784 to .815).

Lab Day Physiological Measures. All physiological measures below (with the exception of cortisol and anthropometrics) were recorded using sensors or electrodes, which were attached to wireless transmitters (Biopac Systems, Inc., USA), which sent physiological signals to a processor module (MP150; Biopac Systems, Inc., USA). All signals were recorded using AcqKnowledge 4.2 software offline (Biopac Systems, Inc., USA), and was analyzed using MindWare software (MindWare Technologies, USA). During the lab visit, the experimenter marked the time points in AcqKnowledge for ANS baseline, TSST introduction, TSST

preparation time, TSST speech task, and TSST math task, identifying periods of interest for analysis of physiological activity.

For all ANS measures below, data were available for were 7 key time periods of interest: baseline (5 minutes), the time when participants first saw the TSST committee and received instructions about the upcoming tasks (3 minutes), the TSST anticipatory stress period during speech preparation (3 minutes), the speech task (5 minutes), the math task (5 minutes), immediately post-TSST (2 minutes), during "after" eating (5 minutes), and immediately post-"after" eating (5 minutes). For each time period, each ANS outcome was calculated in MindWare in 1-minute segments.

In order to examine the fast response of each ANS outcome, the last minute of baseline and the first minute of each subsequent time period were analyzed. If data for one of these given minutes was too noisy to analyze, then the most proximal analyzable segment for that time period was entered instead.

Heart rate variability and pre-ejection period. Electrocardiography (ECG) and impedance cardiography (ICG) were used to further assess ANS activation, including outcomes of heart rate variability (HRV) and pre-ejection period (PEP). For ECG administration, three general spot electrodes (Biopac Systems, Inc., USA) were placed, with one on participants' lowest left rib, lowest right rib, and right collar bone. For ICG administration, four bioimpedance strip electrodes (Biopac Systems, Inc., USA) were placed, with two on the back of the neck and two on the lower back. A small amount of gel was applied to each of strip electrode button before placement.

Heart rate is calculated as the number of heartbeats per minute and is recorded in units of beats per minute. HRV can be defined at its simplest level as the difference between maximum

HR and minimum HR for a given individual. Although HRV is influenced by both sympathetic and parasympathetic control, researchers can deconstruct the variability of this measure to examine these influences in isolation (Mendes, 2009). I used time-domain estimation to compute RMSSD (the root mean square of the difference of successive R-R intervals), which is recorded in milliseconds (Mendes, 2009). Higher RMSSD indicates greater parasympathetic activation (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). To correct for normality, RMSSD values were log transformed prior to hypothesis testing.

PEP is considered one of the purest measures of SNS activity (Mendes, 2009), and is defined as the time elapsed from the contraction of the left ventricle (i.e., the Q point on the ECG wave) to the opening of the aortic value (i.e., the B point on the first derivative of the impedance waveform). PEP is recorded in milliseconds, and smaller values indicate greater sympathetic activity. Values of greater than 150 ms were considered outliers and classified as missing data. To correct for normality, PEP values were squared prior to hypothesis testing.

Respiration. Respiratory rate and depth was measured using a strain gauge strap wrapped around the upper torso and placed immediately under the arms, which captured pressure during inspiration and expiration. Although some researchers factor respiratory rate into their analyses of HRV, whether or not this is important is debatable in the literature (Mendes, 2009); therefore, this study did not take this variable into account in HRV analyses.

Salivary cortisol. Salivary cortisol samples were collected at baseline, and at 15, 25, and 60 minutes post-termination of the TSST. Immediately prior to collection of the 15-minute cortisol sample, all participants were asked to swish their mouths with water 2-3 times, given that participants in conditions 3 and 4 had consumed food within 10-15 minutes of this sample.

Although participants in all other conditions had not consumed food within 10-15 minutes of this sample, all participants rinsed with water for standardization purposes. Saliva samples were frozen at -20 degrees Celcius. Salivary cortisol levels were assayed at the Technical University of Dresden, Germany using chemiluminescence immunoassay and single determination assays.

Raw cortisol values were first log transformed to normalize the cortisol distribution. Then, following the recommendation of Adam and Kumari (2009), log transformed values found to be more than 3 standard deviations above or below the mean for each time point were winsorized. This applied to only 1 of the 600 total samples. Cortisol reactivity typically peaks at 15-25 minutes after a stressor has ended (Kudielka et al., 2007), and mean cortisol values at each time point across the entire sample were analyzed to confirm the point of maximal reactivity (also the start of the recovery period).

Anthropometrics. Participants' weight and height were measured without shoes. Weight was assessed using a Tanita Professional Body Composition Monitor SC-331S, and height was measured using a stadiometer and recorded to the nearest 1/8 inch. BMI was computed using the standard formula [(weight in pounds/height in inches)^2 x 703)], and BMI was incorporated as a covariate in later analyses that include ANS outcomes.

Statistical Analysis

Multilevel analyses outcomes were conducted using SAS University Edition software (version 9.4, SAS Institute, USA). All other analyses were conducted using SPSS software (version 24.0, IBM, USA). Statistical significance for all analyses was set at $p < .05$.

Single time point outcomes. ANOVA tests were used to examine main effects of condition on outcomes collected at a single time point. To test for moderation of these effects, the MODPROBE statistical macro (Hayes & Matthes, 2009) was used to examine 2-way

interactions between condition and each moderator of interest (entered as a continuous variable).

Repeated measures outcomes. Multilevel modeling was used to test hypotheses related to repeated measures, as this method is appropriate for modeling data with repeated measures nested within individuals. Here, multilevel modeling allows the simultaneous estimation of both within-subjects variance (repeated measures of psychological and physiological stress) and between-subjects variance (group differences related to experimental condition). Like other prior research (Croswell et al., 2017), this study included age and BMI as covariates in all analyses of HRV and PEP, as these factors can influence physiological outcomes.[2]

Piecewise multilevel growth curve modeling was used to test whether healthy and unhealthy comfort eating led to decreased reactivity and/or faster recovery for each psychophysiological outcome with repeated measures (i.e., positive mood, negative mood, HRV, PEP, and cortisol) compared to eating no food at all. For example, I tested the effects of eating healthy versus unhealthy versus no food *before* the TSST on cortisol *reactivity* to the TSST, and also tested the effects of eating healthy versus unhealthy versus no food *after* the TSST on cortisol *recovery* from the TSST. For all primary psychophysiological outcomes with repeated measures, I repeated this two-step approach of (1) testing the effect of eating before the TSST on stress reactivity, and (2) testing the effect of eating after the TSST on stress recovery.

Each multilevel model that examined main effects of comfort eating included effects of intervention group, time, and the group by time interaction. To examine moderation of comfort eating effects, additional models were specified to examine the 3-way interactions between intervention group, time, and each moderator of interest (entered as a continuous variable). To follow up on significant 3-way interactions, the Group x Time 2-way interaction was tested

[2] Tests of main effects on physiological outcomes did not change regardless of whether age and BMI were included as covariates.

separately at high and low levels of the moderator, determined by median split. If the 2-way interaction was non-significant in both groups ($p > .05$), the moderation was not probed any further or interpreted as significant.

Results

Participant Characteristics

Descriptive statistics for participants' demographic characteristics and other variables of interest are presented in Table 4. The median family income for the sample was $80,000-89,999.

Manipulation Check

To evaluate whether the TSST was effective in inducing stress, multilevel modeling was used to test for significant stress reactivity from baseline through the TSST for each of the psychophysiological stress outcomes with repeated measures. Results showed that significant reactivity time effects were indeed observed for the outcomes of negative mood, $t(149) = 7.96$, $p < .0001$; positive mood, $t(149) = -5.11$, $p < .0001$; HRV, $t(149) = -8.59$, $p = < .0001$; PEP, $t(142) = -15.18$, $p < .0001$; and cortisol, $t(149) = 4.48$, $p < .0001$. Therefore, these results suggest that the TSST successfully induced stress in the study sample.

Aim 1. Do healthy and unhealthy comfort eating buffer psychological stress?

Rumination and post-stressor appraisals. An omnibus one-way, between-subjects ANOVA test revealed no differences in post-TSST negative thought rumination between the five conditions, $F(4, 145) = 0.06$, $p = .99$. In addition, post-stressor appraisals did not differ between the five conditions, $F(4, 145) = 0.79$, $p = .53$.[3]

[3] These two results did not change when demographic variables that were significantly associated with each outcome (i.e., age and chronic perceived stress for rumination; age and income for post-stressor appraisals) were included as covariates in these tests.

Table 4

Study 1 Sample Demographics

Characteristic	***n***	***M (SD)* or %**	**Min-Max**
Age	150	20.24 (2.21)	18-37
Race/ethnicity	150		
Asian, Asian American, Pacific Islander	68	45.3	
White/Anglo or European American	35	23.3	
Hispanic/Latino(a)	22	14.7	
Bi-racial	14	9.3	
Arabic/Middle Eastern	4	2.7	
Other	4	2.7	
Black/African American, Caribbean	3	2.0	
Family income			
Less than $10,999	4	2.7	
$10,000 - $19,999	7	4.7	
$20,000 - $29,999	10	6.7	
$30,000 - $39,999	11	7.3	
$40,000 - $49,999	11	7.3	
$50,000 - $59,999	11	7.3	
$60,000 - $69,999	12	8.0	
$70,000 - $79,999	8	5.3	
$80,000 - $89,999	12	8.0	
$90,000 - $99,999	6	4.0	
$100,000 - $124,999	20	13.3	
$125,000 - $149,999	8	5.3	
Over $150,000	30	20.0	
Subjective social status (school)	150	7.29 (1.22)	4-10
Depressive symptoms (CES-D)	150	10.53 (5.63)	0-23
Perceived stress (PSS)	150	27.05 (6.06)	13-42
Trait emotional eating (DEBQ)	150	2.36 (0.81)	1.00-4.46
Comfort eating expectations	150	3.46 (1.04)	1.00-5.80
Body mass index	150	22.45 (3.48)	15.97-35.20

Note. CESD = Centers for Epidemiological Studies Depression Scale; PSS = Perceived Stress Scale; DEBQ = Dutch Eating Behavior Questionnaire.

Overall mood trajectories. Tables 5 and 6 present averages for negative and positive mood at each time point by condition, respectively. In addition, Figures 2 and 3 also display negative and positive mood trajectories by condition, respectively.

As shown in Table 5, negative mood reactivity to the stressor peaked in the overall sample at immediately post-"before" eating (PANAS 2), $M = 21.36$, $SD = 6.13$. Negative mood did not change significantly from PANAS 2 to PANAS 3 (immediately post-TSST; overall sample $M = 21.34$, $SD = 8.89$), $F(1,149) = 0.001$, $p = .98$. However, negative mood did decrease significantly from immediately post-TSST to immediately post-"after" eating, $F(1,149) = 132.84$, $p = <.001$. Therefore, in hypothesis testing the mood reactivity period included the 3 time points from baseline through immediately post-TSST, and the recovery period included the 3 time points from immediately post-TSST through 1-hour post-TSST.

As shown in Table 6, positive mood declined from baseline through immediately post-TSST; however, it did not recover and instead continued to decline through the remainder of the lab visit. Therefore, for conceptual reasons, the same time points that were used in reactivity and recovery analyses for negative mood were also used for positive mood.

Table 5

Study 1 Negative Mood Reactivity and Recovery by Condition

Group	**Baseline** ***M* (*SD*)**	**Immediately Post-"Before" Eating** ***M* (*SD*)**	**Immediately Post-TSST** ***M* (*SD*)**	**Immediately Post-"After" Eating** ***M* (*SD*)**	**1 Hour Post-TSST** ***M* (*SD*)**
Unhealthy-before	15.73 (4.29)	22.03 (5.53)	21.47 (8.26)	16.00 (5.25)	12.57 (2.33)
Healthy-before	14.73 (2.63)	20.37 (5.88)	21.70 (9.16)	15.97 (5.46)	13.00 (3.64)
Unhealthy-after	14.93 (3.90)	20.03 (7.02)	20.13 (8.59)	14.97 (4.52)	12.23 (1.91)
Healthy-after	15.70 (4.68)	21.77 (5.38)	21.17 (7.80)	14.80 (3.57)	12.77 (2.39)
No food	16.23 (6.05)	22.60 (6.69)	22.23 (10.82)	16.23 (7.20)	12.07 (2.08)
Total sample	15.47 (4.42)	21.36 (6.13)	21.34 (8.89)	15.59 (5.30)	12.53 (2.53)

Note. TSST = Trier Social Stress Test.

Table 6

Study 1 Positive Mood Reactivity and Recovery by Condition

Group	Baseline *M* (*SD*)	Immediately Post-"Before" Eating *M* (*SD*)	Immediately Post-TSST *M* (*SD*)	Immediately Post-"After" Eating *M* (*SD*)	1 Hour Post-TSST *M* (*SD*)
Unhealthy-before	25.60 (6.64)	26.00 (6.97)	22.47 (7.70)	19.67 (6.94)	19.57 (5.81)
Healthy-before	28.53 (7.98)	27.33 (10.97)	24.23 (10.60)	21.83 (9.50)	22.00 (8.39)
Unhealthy-after	25.33 (7.44)	27.30 (8.63)	23.87 (8.37)	22.90 (7.47)	20.47 (8.02)
Healthy-after	24.43 (8.65)	24.50 (7.51)	20.83 (7.32)	20.27 (7.86)	18.90 (7.39)
No food	28.03 (8.13)	25.70 (7.24)	23.77 (8.47)	19.57 (7.12)	21.27 (7.78)
Total sample	26.39 (7.86)	26.17 (8.35)	23.03 (8.55)	20.85 (7.84)	20.44 (7.51)

Note. TSST = Trier Social Stress Test.

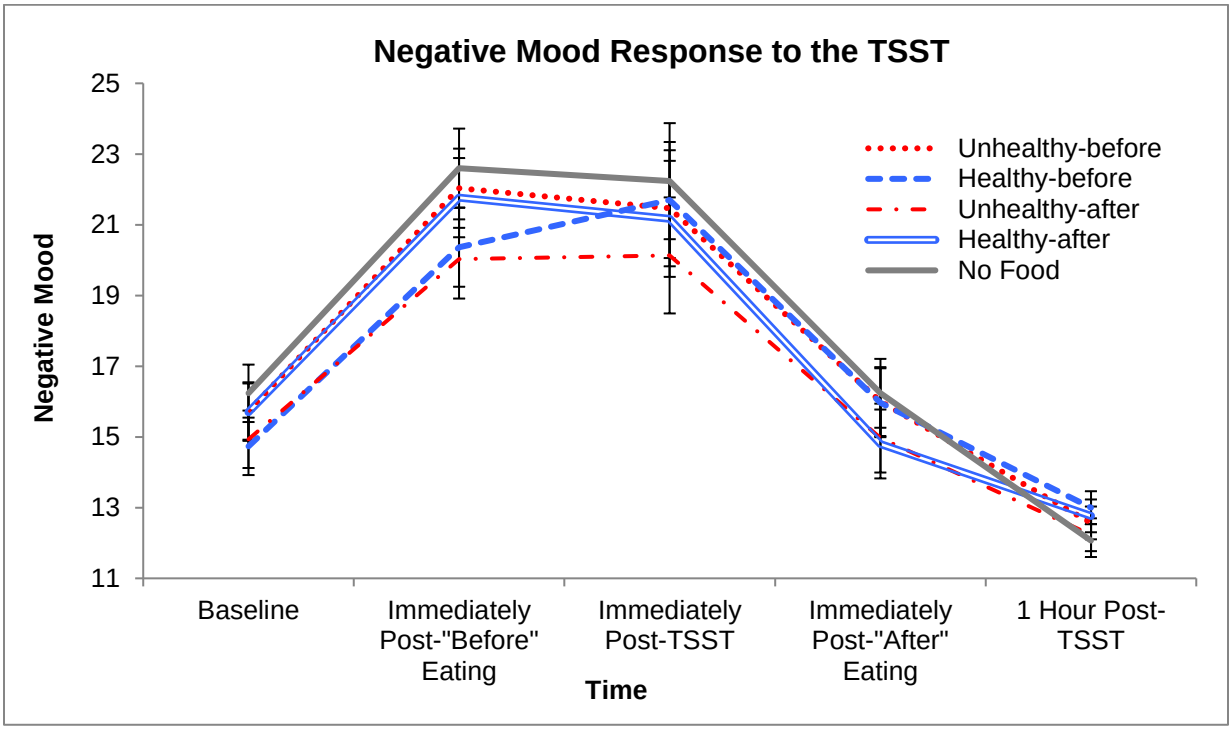


Figure 2. Negative mood response to the Trier Social Stress Test (TSST) in Study 1. Scores were calculated from the negative mood subscale of the Positive and Negative Affect Schedule. Error bars represent standard errors.

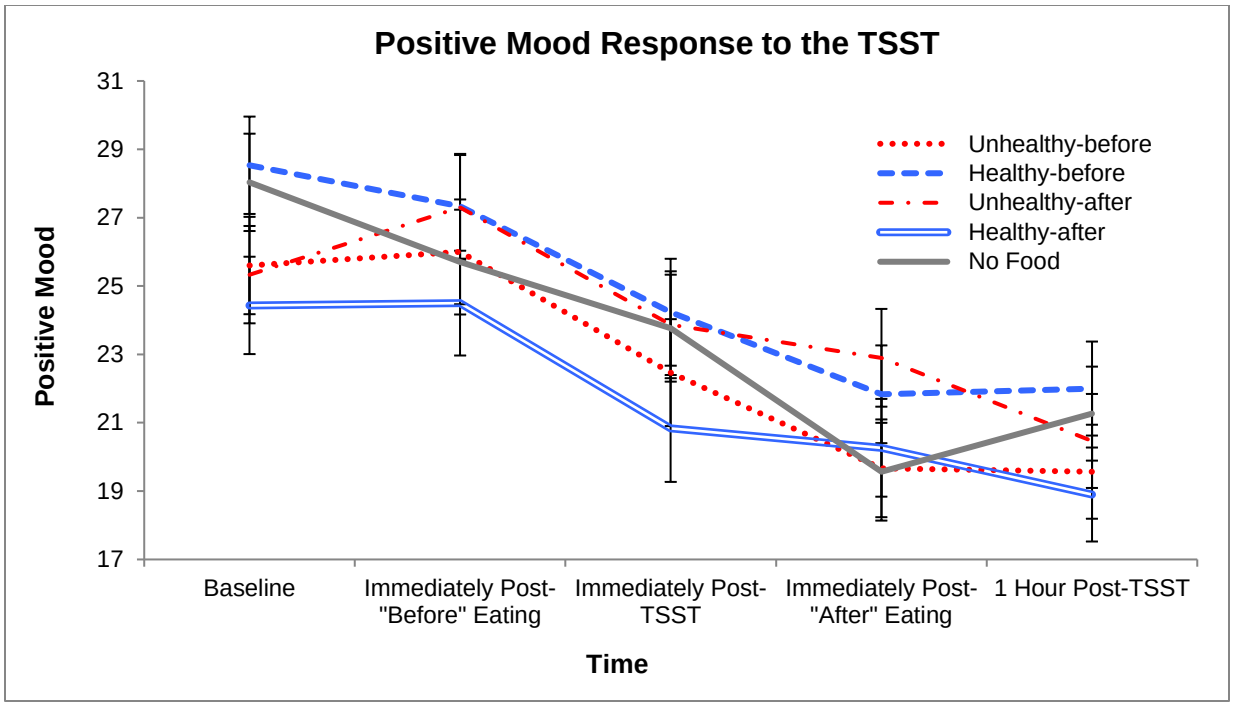


Figure 3. Positive mood response to the Trier Social Stress Test (TSST) in Study 1. Scores were calculated from the positive mood subscale of the Positive and Negative Affect Schedule. Error bars represent standard errors.

Mood reactivity. A base model of negative mood reactivity that included only a random slope was used; when a random intercept was also added to the model, the program did not generate an estimate for this variance component. This model with only a random slope fit better than a model without this component (deviance of 2887.3 vs. 3010.7; deviance change $\chi^2(1.5)$ $p < .0001$). In this initial model, negative mood increased significantly over time, $t(250) = 7.02$, $p < .0001$. In contrast, a base model of positive mood reactivity that included both a random slope and random intercept was used, as this model fit better than one without these components (deviance of 2954.9 vs. 3176.7; deviance change $\chi^2(2)$ $p < .0001$). In this initial model, positive mood decreased significantly over time, $t(149) = -5.11$, $p < .0001$.

As shown in Table 7, negative and positive mood reactivity trajectories each did not differ when comparing the unhealthy-before group, the healthy-before group, and the remaining groups collapsed (all of which had consumed no food by this point in the study).

Mood recovery. A base model of negative mood recovery that included both a random slope and random intercept was used, as this model fit better than one without these components (deviance of 2611.0 vs. 2914.7; deviance change $\chi^2(2)$ $p < .0001$). In this initial model, the negative mood decreased significantly over time, $t(149) = -12.48$, $p < .0001$. Similarly, a base model of positive mood recovery that included both a random slope and random intercept was used, as this model fit better than one without these components (deviance of 2914.8 vs. 3144.1; deviance change $\chi^2(2)$ $p < .0001$). In this initial model, positive mood decreased significantly over time, $t(149) = -4.16$, $p < .0001$.

Also shown in Table 7, negative and positive mood recovery trajectories each did not differ when comparing the unhealthy-after group, healthy-after group, and control group.

Table 7

Study 1 Tests of Mood Reactivity and Recovery by Condition

Test	**Estimate**	***SE***	***df***	***t***	***p***	**95% CI**
Positive mood reactivity						
Unhealthy-before vs. No food	-0.01	0.85	118	-0.01	.990	[-1.69, 1.67]
Healthy-before vs. No food	-0.59	0.87	118	-0.68	.497	[-2.32, 1.13]
Unhealthy-before vs. Healthy-before	0.58	0.99	58	0.59	.559	[-1.40, 2.57]
Negative mood reactivity						
Unhealthy-before vs. No food	0.09	1.10	201	0.08	.936	[-2.08, 2.25]
Healthy-before vs. No food	0.71	1.10	199	0.64	.523	[-1.47, 2.88]
Unhealthy-before vs. Healthy-before	-0.62	1.25	09.3	-0.49	.624	[-3.11, 1.88]
Positive mood recovery						
Unhealthy-after vs. No food	-0.45	1.05	58	-0.43	.670	[-2.55, 1.65]
Healthy-after vs. No food	0.28	1.03	58	0.27	.784	[-1.78, 2.34]
Unhealthy-after vs. Healthy-after	-0.73	0.95	58	-0.77	.445	[-2.64, 1.18]
Negative mood recovery						
Unhealthy-after vs. No food	1.13	1.24	58	0.91	.366	[-1.36, 3.62]
Healthy-after vs. No food	0.88	1.21	58	0.73	.469	[-1.54, 3.31]
Unhealthy-after vs. Healthy-after	0.25	1.06	58	0.24	.814	[-1.86, 2.36]

Note. For reactivity analyses only, the "no food" group collapses the control group and the "after" eating groups together to maximize power, as these groups were indistinguishable at this point in the study. CI = confidence interval.

Aim 2. Do healthy and unhealthy comfort eating buffer physiological stress?

Physiological reactivity and recovery. Table 8 presents the results of tests examining main effects of condition on the physiological reactivity and recovery of HRV, PEP, and cortisol.

Table 8

Study 1 Tests of Physiological Reactivity and Recovery by Condition

Test	Estimate	*SE*	*df*	*t*	*p*	95% CI
RMSSD reactivity						
Unhealthy-before vs. No food	-0.02	0.06	238	-0.26	.793	[-0.14, 0.11]
Healthy-before vs. No food	0.00	0.06	238	0.02	.982	[-0.12, 0.13]
Unhealthy-before vs. Healthy-before	-0.02	0.08	118	-0.24	.814	[-0.17, 0.13]
PEP reactivity						
Unhealthy-before vs. No food	-347.88	421.74	230	-0.82	.410	[-1178.85, 483.09]
Healthy-before vs. No food	-184.41	413.77	229	-0.45	.656	[-999.69, 630.88]
Unhealthy-before vs. Healthy-before	-231.10	531.50	107	-0.43	.665	[-1284.69, 822.49]
Cortisol reactivity						
Unhealthy-before vs. No food	0.16	0.19	118	0.80	.427	[-0.23, 0.54]
Healthy-before vs. No food	-0.07	0.20	118	-0.33	.741	[-0.46, 0.33]
Unhealthy-before vs. Healthy-before	0.22	0.21	58	1.07	.287	[-0.19, 0.63]
RMSSD recovery						
Unhealthy-after vs. No food	0.52	0.04	118	1.17	.245	[-0.04, 0.14]
Healthy-after vs. No food	0.01	0.04	118	0.18	.861	[-0.08, 0.10]
Unhealthy-after vs. Healthy-after	0.04	0.05	58	0.82	.413	[-0.06, 0.15]
PEP recovery						
Unhealthy-after vs. No food	156.57	551.27	114	0.28	.777	[-935.49, 1248.63]
Healthy-after vs. No food	375.10	631.31	111	0.59	.554	[-875.86, 1626.07]
Unhealthy-after vs. Healthy-after	-218.53	593.93	111	-0.37	.714	[-1395.49, 958.41]
Cortisol recovery						
Unhealthy-after vs. No food	-0.02	0.11	58	-0.15	.883	[-0.24, 0.21]
Healthy-after vs. No food	0.05	0.11	58	0.47	.637	[-0.16, 0.26]
Unhealthy-after vs. Healthy-after	-0.07	0.10	58	-0.69	.495	[-0.26, 0.13]

Note. For reactivity analyses only, the "No food" group collapses the control group and the "after" eating groups together to maximize power, as these groups were indistinguishable at this point in the study. RMSSD = root mean square of the difference of successive R-R intervals; PEP = pre-ejection period; CI = confidence interval.

HRV reactivity. Table 9 and Figure 4 present HRV trajectories by condition. As shown there, HRV values reached their nadir during the speech task, indicating peak reactivity. In order to temporally examine the causal impact of "before" eating on HRV reactivity, the reactivity period included only the 3 time points from the instructions period through the speech period (i.e., the baseline time point was excluded from analysis). In other words, "before" eating can not

have a causal impact on change from baseline to the instructions period; therefore, reactivity analysis begins at the time point immediately preceding "before" eating: the instructions period.

The initial HRV reactivity model included only a random intercept; adding a random slope to this model did not significantly improve model fit (deviance of 754.2 with vs. 756.5 without; deviance change $\chi^2(1.5)$ $p = .25$). This random intercept only model fit better than a model without a random intercept (deviance = 908.9; deviance change $\chi^2(1.5)$ $p < .0001$). In this chosen base reactivity model, HRV decreased significantly over time from the TSST instructions period through the speech task, $t(299) = -8.42$, $p < .0001$.

As shown in Table 8, HRV reactivity trajectories did not differ when comparing the unhealthy-before, healthy-before, and no food groups to one another.

HRV recovery. In order to temporally examine the causal impact of "after" eating on HRV recovery, the recovery period included only the 3 time points from immediately post-TSST through immediately post-"after" eating. That is, although HRV began to recover earlier in the lab visit (starting from the speech task onward), "after" eating can not have a causal impact until it occurs later in the lab visit; therefore, the recovery period for hypothesis testing begins at the time point immediately preceding "after" eating.

A base model of HRV recovery that included both a random slope and random intercept was used, as this model fit better than one without these components (deviance of 623.6 vs. 858.9; deviance change $\chi^2(2)$ $p < .0001$). In this initial model, the HRV did not change significantly over time, $t(149) = 0.85$, $p = .40$.

As shown in Table 8, HRV recovery trajectories did not differ when comparing the unhealthy-after, healthy-after, and no food groups to one another.

Table 9

Study 1 RMSSD Reactivity and Recovery by Condition

Group	Baseline *M* (*SD*)	Instructions *M* (*SD*)	Preparation *M* (*SD*)	Speech *M* (*SD*)	Math *M* (*SD*)	Immediately Post-TSST *M* (*SD*)	During "After" Eating *M* (*SD*)	Immediately Post-"After" Eating *M* (*SD*)
Unhealthy-before	44.71 (29.96)	45.02 (23.52)	45.08 (22.29)	31.31 (21.78)	39.08 (19.75)	50.15 (22.37)	51.05 (31.73)	54.01 (29.67)
Healthy-before	51.20 (32.88)	45.38 (32.82)	55.03 (50.78)	27.03 (12.54)	40.70 (23.55)	57.46 (45.70)	55.38 (44.27)	55.52 (35.67)
Unhealthy-after	47.72 (23.19)	44.24 (24.89)	46.63 (32.45)	36.95 (33.29)	41.79 (27.11)	55.37 (38.33)	38.86 (21.65)	45.04 (24.78)
Healthy-after	37.97 (20.23)	31.54 (15.81)	35.89 (22.34)	24.87 (19.11)	34.87 (16.70)	40.67 (24.77)	39.03 (32.24)	46.88 (30.81)
No food control	39.55 (25.01)	33.14 (23.52)	41.22 (34.77)	20.39 (18.44)	30.41 (16.17)	40.75 (31.48)	40.82 (22.10)	42.50 (23.25)
Total sample	44.23 (26.75)	39.86 (25.15)	44.77 (34.30)	28.11 (22.54)	37.37 (21.21)	48.88 (33.95)	45.03 (31.85)	48.79 (29.25)

Note. Raw values are presented here. Transformed values were used in all analyses. RMSSD = root mean square of the difference of successive R-R intervals; TSST = Trier Social Stress Test.

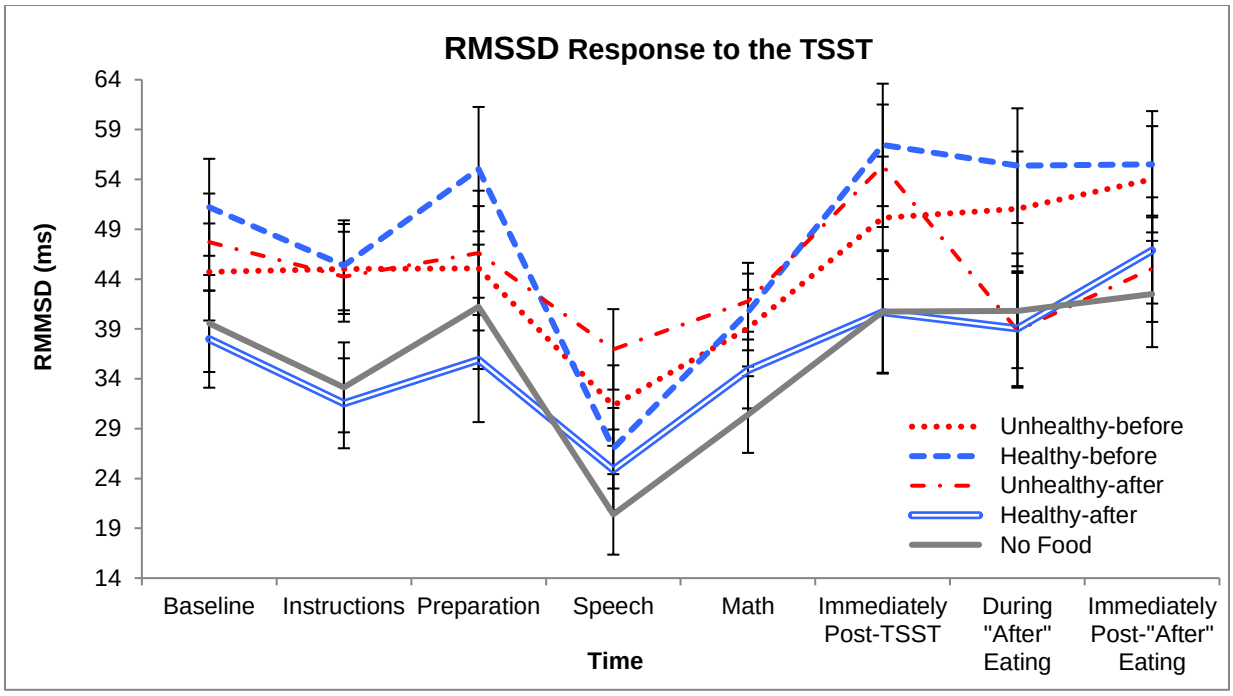


Figure 4. RMSSD response to the Trier Social Stress Test (TSST) in Study 1. Raw values are presented here. RMSSD = root mean square of the difference of successive R-R intervals. Error bars represent standard errors.

PEP reactivity. Table 10 and Figure 5 presents PEP trajectories by condition. As shown there, PEP values reached their nadir during the speech task. Similar to the analyses for HRV reactivity, in order to temporally examine the causal impact of "before" eating on PEP reactivity, the reactivity period included only the 3 time points from the instructions period through the speech period (i.e., the baseline time point was excluded from analysis).

The initial PEP reactivity model included only a random intercept; adding a random slope to this model did not significantly improve model fit (deviance of 8309.5 with vs. 8310.6 without; deviance change $\chi^2(1.5)$ $p = .44$). This random intercept only model fit better than a model without a random intercept (deviance = 8468.4; deviance change $\chi^2(1.5)$ $p < .0001$). In this chosen base reactivity model, PEP decreased significantly over time from the TSST instructions period through the speech task, $t(285) = -14.39$, $p < .0001$.

Table 10

Study 1 PEP Reactivity and Recovery by Condition

Group	Baseline *M* (*SD*)	Instructions *M* (*SD*)	Preparation *M* (*SD*)	Speech *M* (*SD*)	Math *M* (*SD*)	Immediately Post-TSST *M* (*SD*)	During "After" Eating *M* (*SD*)	Immediately Post-"After" Eating *M* (*SD*)
Unhealthy-before	123.00 (15.81)	115.56 (16.96)	107.37 (18.34)	89.07 (20.56)	101.56 (18.13)	104.78 (16.73)	120.04 (18.35)	116.96 (14.59)
Healthy-before	116.71 (13.81)	115.92 (15.33)	104.88 (18.27)	92.08 (19.02)	100.88 (24.03)	98.25 (17.78)	111.29 (19.42)	109.71 (21.09)
Unhealthy-after	122.72 (22.01)	119.45 (20.53)	100.86 (16.84)	97.93 (20.95)	109.93 (22.53)	109.93 (20.23)	122.00 (16.95)	121.52 (12.10)
Healthy-after	123.56 (15.27)	119.16 (20.83)	105.80 (23.09)	98.76 (21.93)	105.52 (16.24)	106.40 (16.81)	115.68 (24.79)	117.96 (29.18)
No food control	124.64 (16.36)	110.68 (25.97)	102.18 (25.57)	90.11 (26.31)	101.96 (24.41)	106.07 (25.65)	120.86 (15.27)	115.07 (31.68)
Total sample	122.26 (17.02)	116.12 (20.36)	106.29 (20.59)	93.59 (22.02)	104.09 (21.33)	105.30 (19.93)	118.24 (19.18)	116.44 (22.92)

Note. Raw values are presented here. Transformed values were used in all analyses. PEP = pre-ejection period; TSST = Trier Social Stress Test.

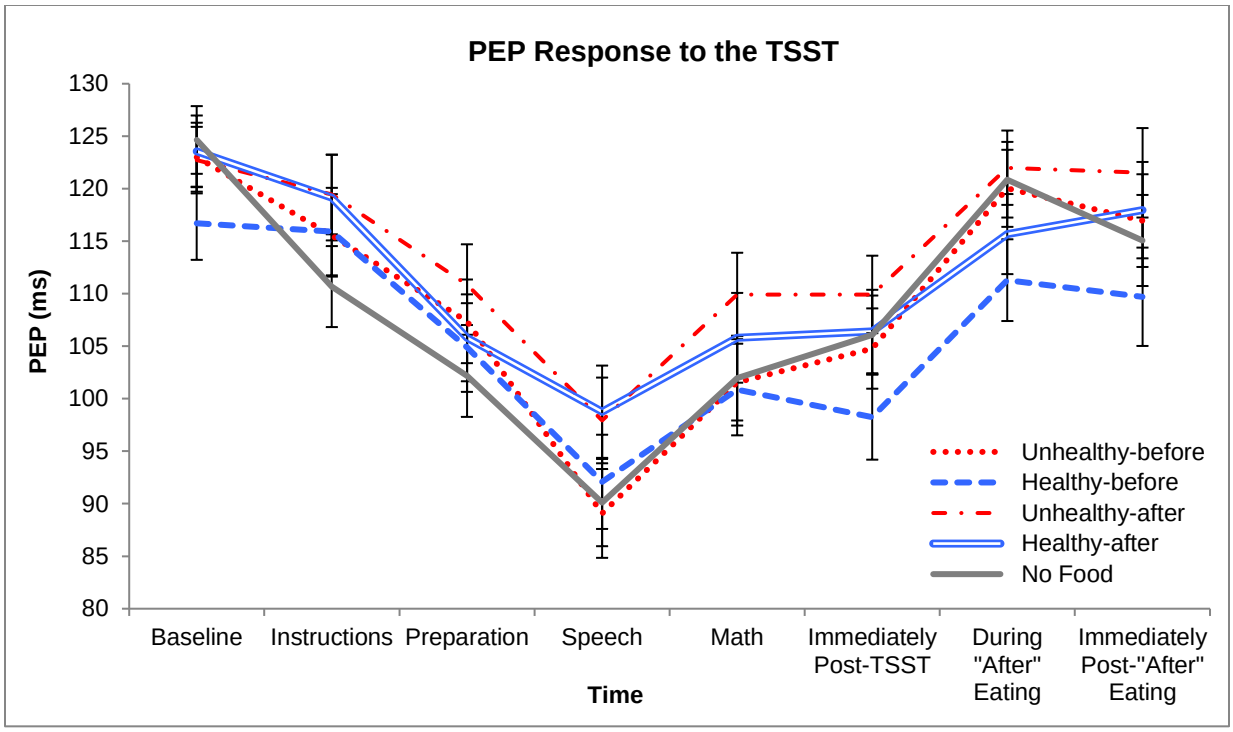


Figure 5. Pre-ejection period (PEP) response to the Trier Social Stress Test (TSST) in Study 1. Raw values are presented here. Error bars represent standard errors.

As shown in Table 8, PEP reactivity trajectories each did not differ when comparing the unhealthy-before, healthy-before, and no food groups.

PEP recovery. In order to temporally examine the causal impact of "after" eating on PEP recovery, the recovery period included only the 3 time points from immediately post-TSST through immediately post-"after" eating. That is, although PEP began to recover earlier in the lab visit (starting from the speech task onward), "after" eating can not have a causal impact until it occurs later in the lab visit; therefore, the recovery period for hypothesis testing begins at the time point immediately preceding "after" eating.

The initial PEP recovery model included only a random intercept, as adding a random slope to the model did not significantly improve model fit (deviance of 8348.7 with vs. 8350.8 without; deviance change $\chi^2(1.5)$ p = .249). This model also fit better than one with only a

random slope (deviance of 8424.3, deviance change $\chi^2(1.5)$ $p < .0001$) and one with neither a random intercept nor random slope (deviance of 8449.0, deviance change $\chi^2(1.5)$ $p < .001$). In this initial model, PEP increased significantly over time, $t(285) = 7.26$, $p < .0001$.

As shown in Table 8, PEP recovery trajectories did not differ when comparing the unhealthy-after, healthy-after, and no food groups.

Cortisol reactivity. Table 11 and Figure 6 presents raw cortisol trajectories by condition. As shown in the figure, cortisol reactivity to the stressor peaked at 15-minutes after the TSST, and began to recover from then onward. Therefore, in hypothesis testing the reactivity period included the 2 time points of baseline and 15-minutes post-TSST, and the recovery period included the 3 time points of 15-, 25-, and 60-minutes post-TSST.

Table 11

Study 1 Cortisol Reactivity and Recovery by Condition

Group	**Baseline** ***M* (*SD*)**	**15 Minutes Post-TSST** ***M* (*SD*)**	**25 Minutes Post-TSST** ***M* (*SD*)**	**60 Minutes Post-TSST** ***M* (*SD*)**
Unhealthy-before	4.23 (2.55)	6.71 (4.26)	6.16 (3.12)	4.27 (1.86)
Healthy-before	6.13 (11.32)	7.42 (7.31)	7.00 (5.96)	5.30 (3.23)
Unhealthy-after	4.83 (2.72)	8.92 (7.12)	8.21 (6.39)	5.96 (4.42)
Healthy-after	5.27 (2.85)	7.66 (8.85)	7.12 (6.48)	4.76 (2.61)
No food	5.39 (3.26)	10.89 (11.14)	8.65 (7.79)	6.51 (4.99)
Total sample	5.17 (5.63)	8.32 (8.09)	7.43 (6.13)	5.36 (3.65)

Note. Raw values are presented here. Transformed values were used in all analyses. TSST = Trier Social Stress Test.

The initial cortisol reactivity model included only a random intercept; when a random slope was also added to the model, the program did not generate an estimate for the residual. This random intercept only model fit better than a model without a random intercept (deviance = 671.1 vs. 690.1; deviance change $\chi^2(1.5)$ $p < .0001$), and also fit better than a model with only a random slope (deviance = 671.1 vs. 671.1; deviance change $\chi^2(1.5)$ $p = .029$). In this chosen

base reactivity model, cortisol increased significantly over time from the TSST instructions period through the speech task, $t(149) = 4.48$, $p < .0001$.

As shown in Table 8, cortisol reactivity trajectories did not differ between the unhealthy-before, healthy-before, and no food groups.

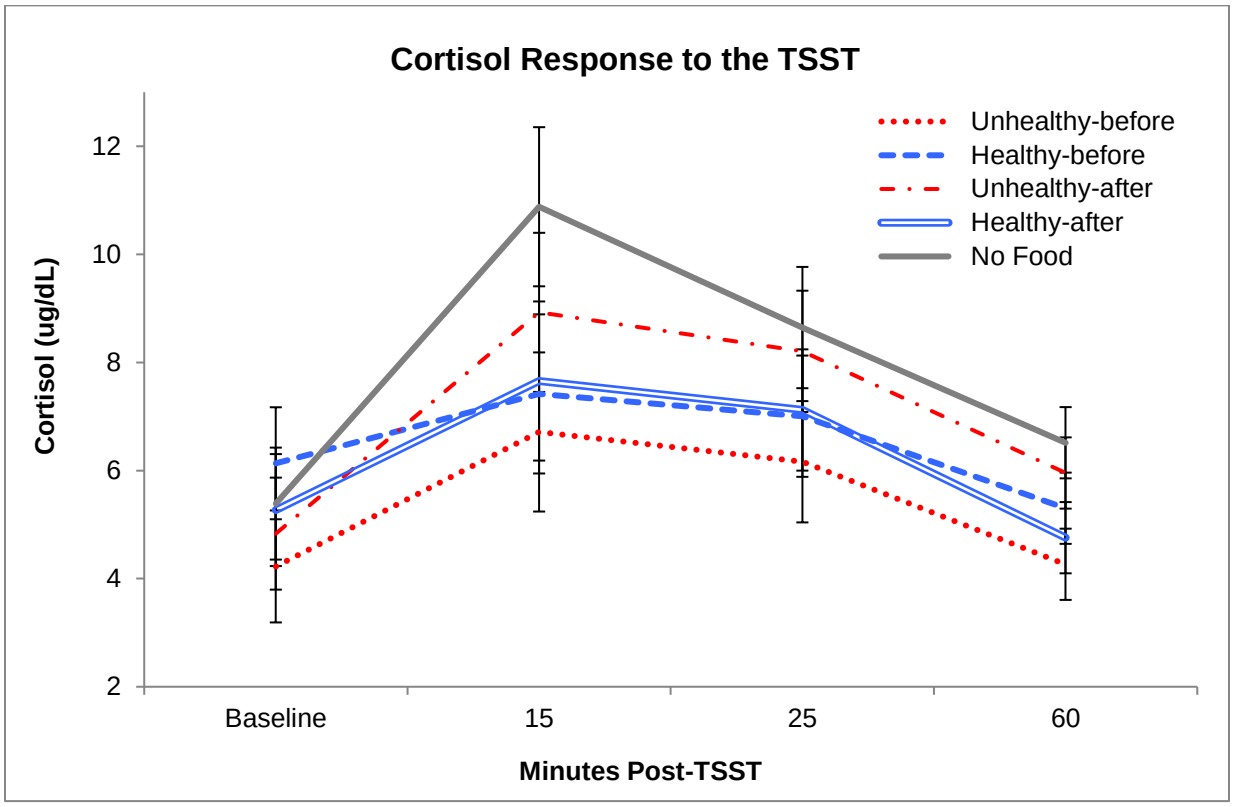


Figure 6. Cortisol response to the Trier Social Stress Test (TSST) in Study 1. Raw values are presented here. Error bars represent standard errors.

Cortisol recovery. The base model of cortisol recovery included both a random slope and random intercept, as this model fit better than one without these components (deviance of 722.1 vs. 1049.5; deviance change $\chi^2(2)$ $p < .0001$). In this initial model, cortisol decreased significantly over time, $t(149) = -4.20$, $p < .0001$.

As shown in Table 8, cortisol recovery trajectories did not differ between the unhealthy-after, healthy-after, and no food groups.

Aim 3: Does the timing of comfort eating affect psychophysiological stress recovery?

Rumination and post-stressor appraisals. An omnibus one-way, between-subjects ANOVA test detected no differences in post-TSST negative thought rumination between the collapsed "before" conditions, the collapsed "after" conditions, and the no food condition, $F(2, 147) = 0.10$, $p = .90$. Similarly, post-stressor appraisals did not differ between these three groups, $F(2, 147) = 1.03$, $p = .36$.

Mood and physiological outcomes. The same base models of recovery trajectories for the outcomes of positive mood, negative mood, and cortisol that were used for Aims 1-2 were also used here when examining comfort eating timing effects. In addition, for comparisons involving the collapsed "after" groups, base recovery models from Aims 1-2 were also used here for HRV and PEP timing effects.

Before-any versus no food comparisons. In contrast, for the two tests comparing the collapsed "before" groups and the no food control group on the outcomes of HRV and PEP recovery, new initial models were fit such that the recovery period included the 5 time points from the speech task through immediately post-"after" eating. That is, given that no "after" conditions were involved in these comparisons, data from all time points from the speech task onward were included to maximize power.

The initial HRV recovery model included both a random intercept and a random slope, as this model fit better than one without these variance components (deviance of 1100.6 with vs. 1464.9 without; deviance change $\chi^2(2)$ $p < .0001$). In this initial model, HRV increased significantly over time, $t(149) = 10.35$, $p < .0001$.

The initial PEP recovery model included both a random intercept and a random slope, as this model fit better than one without these variance components (deviance of 13844.8 with vs.

14142.8 without; deviance change $\chi^2(2)$ $p < .0001$). In this initial model, PEP increased significantly over time, $t(141) = 12.24$, $p < .0001$.

The initial PEP recovery model included both a random intercept and a random slope, as this model fit better than one without these variance components (deviance of 13844.8 with vs. 14142.8 without; deviance change $\chi^2(2)$ $p < .0001$). In this initial model, PEP increased significantly over time, $t(141) = 12.24$, $p < .0001$.

Results. As shown in Table 12, the collapsed "before" conditions, the collapsed "after" conditions, and the no food control condition were not significantly different in their recovery trajectories for positive mood, negative mood, RMSSD, PEP, or cortisol.

Table 12

Study 1 Tests of Psychophysiological Recovery by Comfort Eating Timing

Test	Estimate	*SE*	*df*	*t*	*p*	95% CI
Positive mood recovery						
Before-any vs. No food	-0.03	0.88	88	-0.04	.970	[-1.79, 1.72]
After-any vs. No food	-0.08	0.87	88	-0.10	.924	[-1.82, 1.66]
Before-any vs. After-any	0.05	0.68	118	0.07	.941	[-1.29, 1.39]
Negative mood recovery						
Before-any vs. No food	0.68	1.01	88	0.68	.501	[-1.32, 2.69]
After-any vs. No food	1.01	1.01	88	1.00	.321	[-0.10, 3.02]
Before-any vs. After-any	-0.33	0.74	118	-0.44	.662	[-1.79, 1.14]
RMSSD recovery						
Before-any vs. No food	-0.06	0.03	88	-1.97	.052	[-0.13, 0.00]
After-any vs. No food	-0.05	0.06	88	-0.85	.398	[-0.18, 0.07]
Before-any vs. After-any	-0.01	0.05	118	-0.23	.815	[-0.11, 0.09]
PEP recovery						
Before-any vs. No food	-175.34	243.35	82.8	-0.72	.473	[-659.37, 308.69]
After-any vs. No food	265.84	511.91	169	0.52	.604	[-744.72, 1276.39]
Before-any vs. After-any	62.79	396.08	226	0.16	.874	[-717.69, 843.27]
Cortisol recovery						
Before-any vs. No food	0.01	0.08	88	0.12	.901	[-0.16, 0.18]
After-any vs. No food	0.02	0.09	88	0.18	.855	[-0.16, 0.20]
Before-any vs. After-any	-0.01	0.06	118	-0.10	.923	[-0.13, 0.12]

Note. RMSSD = root mean square of the difference of successive R-R intervals; PEP = pre-ejection period; CI = confidence interval.

Aim 4. Which factors moderate or mediate buffering effects of food type? Specifically, are any stress-dampening effects of healthy or unhealthy comfort eating on psychophysiological stress responses: (1) moderated by comfort eating expectations, trait emotional eating, or chronic stress levels; or (2) mediated by feelings of guilt immediately after food consumption, or sugar content of the food consumed?

Rumination and post-stressor appraisals. Trait emotional eating, comfort eating expectations, and chronic perceived stress each did not interact with the 5-condition omnibus variable to predict negative rumination ($p = .32$, $p = .063$, and $p = .61$, respectively) or post-stressor appraisals ($p = .62$, $p = .43$, and $p = .98$, respectively). Given that there were no main effects of the 5-condition omnibus variable on these two outcomes (see Aim 1), mediation analyses were not conducted.

Mood reactivity moderation. Table 13 displays results from tests of the 3-way interaction terms between condition, time, and each moderator of interest in models of positive and negative mood reactivity. Only one test suggested moderation: the difference in positive mood reactivity between the healthy-before and no food groups appeared to depend upon participants' chronic perceived stress level. However, follow-up analyses examining this condition by time interaction separately in participants exhibiting low ($n = 62$) and high ($n = 58$) PSS (determined by median split) revealed that the positive mood reactivity trajectory was not significantly different between the healthy-before group and the no food groups in either the low-stress or high-stress women, $p = .46$ and $p = .087$, respectively.

Table 13

Study 1 Moderation Analyses for Mood Reactivity by Condition

Test	Estimate	*SE*	*df*	*t*	*p*	95% CI
Positive mood reactivity						
Unhealthy-before vs. No food						
Trait emotional eating	-0.24	1.10	116	-0.22	.825	[-2.43, 1.94]
Comfort eating expectations	0.02	0.86	116	0.03	.978	[-1.67, 1.72]
Chronic perceived stress	-0.17	0.15	116	-1.16	.250	[-0.46, 0.12]
Healthy-before vs. No food						
Trait emotional eating	-1.81	1.15	116	-1.57	.118	[-4.08, 0.47]
Comfort eating expectations	-0.35	0.93	116	-0.38	.708	[-2.20, 1.50]
Chronic perceived stress	-0.41	0.14	116	-2.94	**.004**	[-0.69, -0.13]
Unhealthy-before vs. Healthy-before						
Trait emotional eating	1.56	1.32	56	1.19	.239	[-1.07, 4.20]
Comfort eating expectations	0.37	1.08	56	0.35	.730	[-1.78, 2.53]
Chronic perceived stress	0.24	0.16	56	1.53	.131	[-0.07, 0.56]
Negative mood reactivity						
Unhealthy-before vs. No food						
Trait emotional eating	0.97	1.36	206	0.71	.476	[-1.71, 3.65]
Comfort eating expectations	0.53	1.09	202	0.48	.630	[-1.62, 2.67]
Chronic perceived stress	0.00	0.19	198	-0.01	.992	[-0.37, 0.37]
Healthy-before vs. No food						
Trait emotional eating	0.58	1.41	202	0.41	.680	[-2.19, 3.36]
Comfort eating expectations	0.69	1.15	200	0.60	.548	[-1.58, 2.96]
Chronic perceived stress	0.03	0.18	195	0.18	.857	[-0.32, 0.39]
Unhealthy-before vs. Healthy-before						
Trait emotional eating	0.39	1.57	93.1	0.25	.804	[-2.72, 3.51]
Comfort eating expectations	-0.17	1.30	90.4	-0.13	.897	[-2.76, 2.42]
Chronic perceived stress	-0.03	0.21	86.8	-0.17	.872	[-0.46, 0.39]

Note. Each test represents the 3-way interaction between condition, time, and the moderator of interest. The "No food" group collapses the control group and the "after" eating groups to maximize power, as at this point in the study, these groups were indistinguishable. CI = confidence interval.

Mood recovery moderation. Table 14 displays results from tests of the 3-way interaction terms between condition, time, and each moderator of interest in models of positive and negative mood recovery. Two tests suggested moderated effects.

First, the difference in positive mood recovery between the healthy-after and no food group depended upon participants' chronic perceived stress level. However, follow-up analyses examining this condition by time interaction separately in participants with low (n = 32) and high (n = 28) PSS (determined by median split) revealed that the positive mood recovery trajectory

was not significantly different between the healthy-after group and the no food group in either low-stress or high-stress women, $p = .13$ and $p = .054$, respectively.

Second, the difference in negative mood recovery between the healthy-after and no food group depended upon participants' comfort eating expectations. However, follow-up analyses examining this condition by time interaction separately in participants with low ($n = 35$) and high ($n = 25$) comfort eating expectations (determined by median split) revealed that the negative mood recovery trajectory was not significantly different between the healthy-after group and the no food group in either category, $p = .083$ and $p = .080$, respectively.

Table 14

Study 1 Moderation Analyses for Mood Recovery by Condition

Test	**Estimate**	***SE***	***t*(56)**	***p***	**95% CI**
Positive mood recovery					
Unhealthy-after vs. No food					
Trait emotional eating	-0.35	1.27	-0.28	.784	[-2.89, 2.19]
Comfort eating expectations	1.36	1.120	1.23	.224	[-0.85, 3.57]
Chronic perceived stress	0.25	017	1.44	.155	[-0.10, 0.59]
Healthy-after vs. No food					
Trait emotional eating	-0.81	1.22	-0.66	.511	[-3.25, 1.64]
Comfort eating expectations	0.61	0.91	0.67	.504	[-1.21, 2.43]
Chronic perceived stress	0.36	0.17	2.13	**.038**	[0.02, 0.71]
Unhealthy-after vs. Healthy-after					
Trait emotional eating	0.46	1.23	0.37	.712	[-2.01, 2.92]
Comfort eating expectations	0.75	1.03	0.72	.472	[1.32, 2.81]
Chronic perceived stress	-0.12	0.15	-0.77	.447	[-0.43, 0.19]
Negative mood recovery					
Unhealthy-after vs. No food					
Trait emotional eating	0.12	1.47	0.08	.936	[-2.82, 3.06]
Comfort eating expectations	2.41	1.25	1.92	.060	[-0.10, 4.92]
Chronic perceived stress	0.18	0.21	0.85	.397	[-0.24, 0.59]
Healthy-after vs. No food					
Trait emotional eating	1.01	1.41	0.72	.477	[-1.82, 3.85]
Comfort eating expectations	2.04	1.01	2.02	**.049**	[0.01, 4.07]
Chronic perceived stress	0.02	0.21	0.10	.922	[-0.39, 0.43]
Unhealthy-after vs. Healthy-after					
Trait emotional eating	-0.89	1.35	-0.66	.510	[-3.60, 1.81]
Comfort eating expectations	0.37	1.18	0.31	.755	[-2.00, 2.74]
Chronic perceived stress	0.16	0.17	0.92	.359	[-0.18, 0.50]

Note. Each test represents the 3-way interaction between condition, time, and the moderator of interest. CI = confidence interval.

Mood mediation. Given that no main effects of condition were found for positive or negative mood reactivity or recovery in Aim 1, mediation analyses were not conducted.

Physiological reactivity moderation. Table 15 displays results from tests of the 3-way interaction terms between condition, time, and each moderator of interest in models of HRV, PEP, and cortisol reactivity. Only one test suggested reactivity moderation: the difference in cortisol reactivity between the unhealthy-before and healthy-before groups appeared to depend upon participants' trait emotional eating level (see Figure 7). In participants exhibiting low trait emotional eating (determined by median split; $n = 30$), cortisol reactivity was significantly greater in the unhealthy-before than the healthy-before group, $\beta = 0.73$ ($SE = 0.27$), $t(28) = 2.74$, $p = .011$, 95% CI [0.18, 1.27]. However, in participants exhibiting high trait emotional eating ($n = 30$), cortisol reactivity trajectory did not differ between the unhealthy-before and healthy-before groups, $p = .35$.

Physiological recovery moderation. Table 16 presents results from tests of the 3-way interaction terms between condition, time, and each moderator of interest in models of HRV, PEP, and cortisol recovery. All tests of moderation of physiological recovery were non-significant.

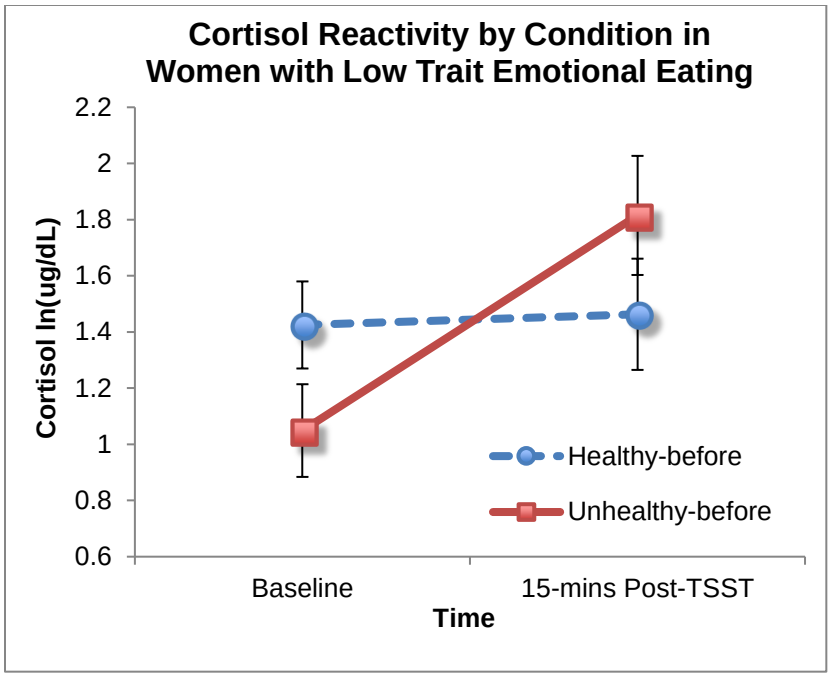
Physiological mediation. Given that no main effects of condition were found for HRV, PEP, or cortisol reactivity or recovery in Aim 2, mediation analyses were not conducted.

Table 15

Study 1 Moderation Analyses for Physiological Reactivity by Condition

Test	Estimate	*SE*	*df*	*t*	*p*	95% CI
RMSSD reactivity						
Unhealthy-before vs. No food						
Trait emotional eating	0.06	0.08	236	0.73	.467	[-0.10, 0.22]
Comfort eating expectations	0.11	0.06	236	1.83	.069	[-0.01, 0.24]
Chronic perceived stress	0.00	0.01	236	-0.38	.706	[-0.03, 0.02]
Healthy-before vs. No food						
Trait emotional eating	-0.08	0.08	236	-0.91	.365	[-0.24, 0.09]
Comfort eating expectations	0.06	0.07	236	0.92	.359	[-0.07, 0.20]
Chronic perceived stress	-0.01	0.01	236	-0.72	.472	[-0.03, 0.01]
Unhealthy-before vs. Healthy-before						
Trait emotional eating	0.14	0.10	116	1.33	.186	[-0.07, 0.34]
Comfort eating expectations	0.05	0.08	116	0.64	.524	[-0.11, 0.21]
Chronic perceived stress	0.00	0.01	116	0.27	.787	[-0.02, 0.03]
PEP reactivity						
Unhealthy-before vs. No food						
Trait emotional eating	545.38	569.09	234	0.96	.339	[-575.82, 1666.58]
Comfort eating expectations	354.75	431.03	229	0.82	.411	[-494.54, 1204.03]
Chronic perceived stress	-86.41	70.96	226	-1.22	.225	[-226.23, 53.41]
Healthy-before vs. No food						
Trait emotional eating	-670.68	543.03	226	-1.24	.218	[-1740.71, 399.36]
Comfort eating expectations	173.92	445.02	228	0.39	.696	[-702.94, 1050.78]
Chronic perceived stress	-74.01	70.30	230	-1.05	.294	[-212.51, 64.50]
Unhealthy-before vs. Healthy-before						
Trait emotional eating	1295.33	726.08	108	1.78	.078	[-143.88, 2734.54]
Comfort eating expectations	148.83	580.35	106	0.26	.798	[-1001.83, 1299.50]
Chronic perceived stress	-5.45	90.54	106	-0.06	.952	[-194.96, 174.05]
Cortisol reactivity						
Unhealthy-before vs. No food						
Trait emotional eating	-0.20	0.25	116	-0.81	.422	[-0.71, 0.30]
Comfort eating expectations	-0.09	0.20	116	-0.46	.644	[-0.48, 0.30]
Chronic perceived stress	-0.03	0.03	116	-0.90	.369	[-0.10, 0.04]
Healthy-before vs. No food						
Trait emotional eating	0.39	0.26	116	1.51	.134	[-0.12, 0.91]
Comfort eating expectations	-0.03	0.21	116	-0.15	.884	[-0.45, 0.39]
Chronic perceived stress	0.01	0.03	116	0.38	.701	[-0.05, 0.08]
Unhealthy-before vs. Healthy-before						
Trait emotional eating	-0.59	0.27	56	-2.21	**.031**	[-1.13, -0.06]
Comfort eating expectations	-0.06	0.23	56	-0.27	.790	[-0.51, 0.39]
Chronic perceived stress	-0.04	0.03	56	-1.23	.225	[-0.11, 0.03]

Note. Each test represents the 3-way interaction between condition, time, and the moderator of interest. The "No food" group collapses the control group and the "after" eating groups to maximize power, as at this point in the study, these three conditions were indistinguishable. RMSSD = root mean square of the difference of successive R-R intervals; PEP = pre-ejection period; CI = confidence interval.



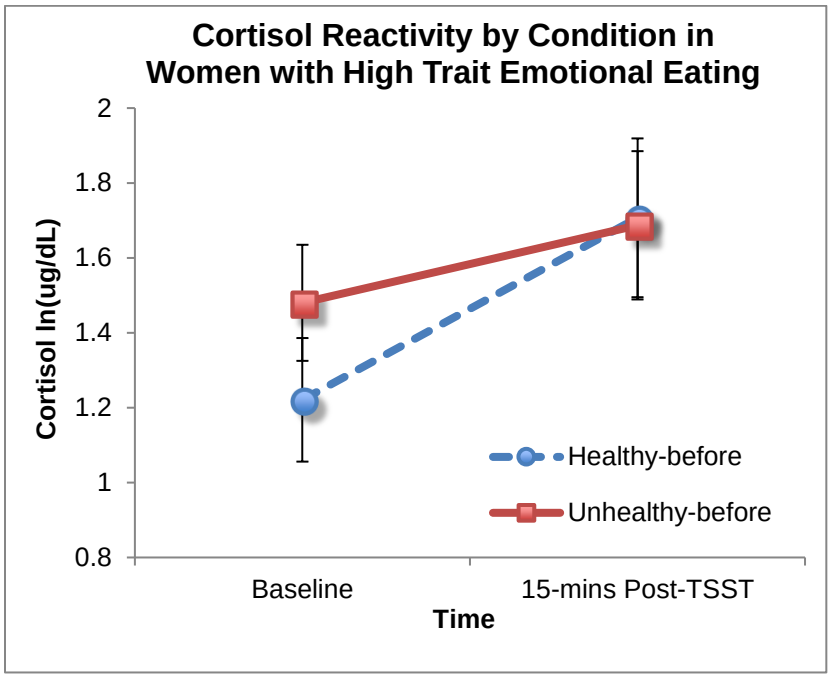


Figure 7. Cortisol reactivity by trait emotional eating category in Study 1. Values are presented at baseline and 15-minutes after termination of the Trier Social Stress Test (TSST). Error bars represent standard errors.

Table 16

Study 1 Moderation Analyses for Physiological Recovery by Condition

Test	Estimate	*SE*	*df*	*t*	*p*	95% CI
RMSSD recovery						
Unhealthy-after vs. No food						
Trait emotional eating	0.03	0.09	56	0.31	.758	[-0.015, 0.20]
Comfort eating expectations	-0.02	0.08	56	-0.24	.815	[-0.17, 0.13]
Chronic perceived stress	0.00	0.01	56	0.16	.876	[-0.02, 0.03]
Healthy-after vs. No food						
Trait emotional eating	-0.11	0.08	56	-1.33	.189	[-0.27, 0.06]
Comfort eating expectations	-0.02	0.06	56	-0.39	.700	[-0.15, 0.10]
Chronic perceived stress	-0.01	0.01	56	-1.01	.315	[-0.04, 0.01]
Unhealthy-after vs. Healthy-after						
Trait emotional eating	0.14	0.09	56	1.44	.157	[-0.05, 0.33]
Comfort eating expectations	0.00	0.08	56	0.08	.939	[-0.16, 0.18]
Chronic perceived stress	0.01	0.01	56	1.18	.242	[-0.01, 0.04]
PEP recovery						
Unhealthy-after vs. No food						
Trait emotional eating	196.21	714.89	112	0.27	.784	[-1220.26, 1612.67]
Comfort eating expectations	-545.82	574.68	112	-0.95	.344	[-1684.48, 592.84]
Chronic perceived stress	-81.54	91.39	112	-0.89	.374	[-262.62, 99.54]
Healthy-after vs. No food						
Trait emotional eating	-340.05	740.03	109	-0.46	.647	[-1806.73, 1126.63]
Comfort eating expectations	300.10	558.86	109	0.54	.592	[807.53, 1407.73]
Chronic perceived stress	-13.11	105.32	109	-0.12	.901	[-221.84, 195.62]
Unhealthy-after vs. Healthy-after						
Trait emotional eating	536.26	815.42	109	0.66	.512	[-1079.90, 2152.42]
Comfort eating expectations	-845.92	656.06	109	-1.29	.200	[-2146.25, 454.41]
Chronic perceived stress	-68.43	05.34	109	-0.72	.475	[-257.39, 120.53]
Cortisol recovery						
Unhealthy-after vs. No food						
Trait emotional eating	0.10	0.14	56	0.73	.467	[-0.17, 0.37]
Comfort eating expectations	0.10	0.12	56	0.81	.424	[-0.14, 0.33]
Chronic perceived stress	0.01	0.02	56	0.38	.704	[-0.03, 0.05]
Healthy-after vs. No food						
Trait emotional eating	0.08	0.12	56	0.61	.544	[-0.17, 0.32]
Comfort eating expectations	0.13	0.09	56	1.38	.174	[-0.06, 0.31]
Chronic perceived stress	0.00	0.02	56	-0.05	.964	[-0.04, 0.04]
Unhealthy-after vs. Healthy-after						
Trait emotional eating	0.02	0.13	56	0.19	.853	[-0.23, 0.27]
Comfort eating expectations	-0.03	0.11	56	-0.28	.781	[-0.25, 0.19]
Chronic perceived stress	0.01	0.02	56	0.51	.609	[-0.02, 0.04]

Note. Each test represents the 3-way interaction between condition, time, and the moderator of interest. RMSSD = root mean square of the difference of successive R-R intervals; PEP = pre-ejection period; CI = confidence interval.

Summary of Findings

Aim 1: Psychological Stress Responses

I hypothesized that compared to a non-food control, both healthy and unhealthy comfort eating would dampen psychological stress reactivity and enhance psychological stress recovery; however, results did not support this hypothesis. Instead, regardless of whether participants ate healthy food, unhealthy food, or no food during their lab visit, they showed similar psychological stress responses in terms of positive and negative mood reactivity and recovery; rumination; and post-stressor appraisals of how the stress tasks actually went.

Aim 2: Physiological Stress Responses

Although I expected that healthy and unhealthy comfort eating would also dampen stress reactivity and enhance stress recovery of physiological markers compared to eating no food at all, this hypothesis was also not supported by the results. On the contrary, there were no differences in stress reactivity and recovery of HRV, PEP, or cortisol between those who ate healthy food, unhealthy food, and no food at all.

Aim 3: Comfort Eating Timing

Results showed that whether participants ate before or after the stressor, both their psychological and physiological markers of stress recovery were no different from one another and also no different from the no-food control group. These findings did not support my hypothesis that comfort eating before the stressor would lead to more favorable psychophysiological stress recovery compared to comfort eating after the stressor.

Aim 4: Moderation and Mediation

I hypothesized that stress-buffering effects of comfort eating would be greater in individuals who: (1) expressed greater expectations that eating will improve mood, (2) exhibited higher scores on trait emotional eating, (3) reported higher chronic stress levels. However, only

one analysis suggested significant moderation: trait emotional eating moderated the effect of condition on cortisol reactivity. Among participants with low trait emotional eating, those who ate healthy food before the stressor did not show significant cortisol reactivity from baseline to 15 minutes post-TSST, whereas those who ate unhealthy food did show significant cortisol reactivity. Among participants with high trait emotional eating, there were no differences in cortisol reactivity between these two conditions.

Regarding mediation, I hypothesized that stress-dampening effects would be greater in individuals who: (1) reported lower feelings of guilt after food consumption in the lab, and (2) consumed a greater amount of sugar from food in the lab. However, given that there were no main effects of comfort eating on psychophysiological stress in Aims 1-3, no further analyses were conducted to test these pathways.

Study 2: Origins of Healthy Comfort Eating

Aims and Hypotheses

Study 2 applied Pavlovian conditioning procedures to the context of healthy comfort eating by randomly assigning participants to one of two conditions. In the intervention group, an initially neutrally-liked healthy fruit (CS) was repeatedly temporally paired with stress reduction (US) that is known to elicit decreased psychophysiological stress (UR). In the control group, participants also repeatedly received the same CS and US, but these stimuli were explicitly unpaired and thus never occurred at the same time.

Aim 1: Examine whether post-intervention fruit CS intake in the lab affects physiological stress and mood differently by experimental condition.

Hypotheses: Fruit CS intake in the lab at post-intervention will elicit a greater increase in HRV and positive mood—as well as a greater decrease in negative mood—in the intervention group than the control group.

Aim 2: Test whether experimental condition affects stress-induced consumption of healthy and unhealthy foods outside of the lab at post-intervention.

Hypotheses: Across 4 days of self-food monitor ting outside of the lab at post-intervention, those in the intervention group will show both increase intake of healthy food and decreased consumption of unhealthy food compared to the control group. With regard to healthy eating outcomes, compared to the control group, the intervention group will show greater intake of fruits, vegetables, and dietary fiber, as well as increased intake of their idiosyncratic fruit CS from prior conditioning trials. For unhealthy outcomes, compared to the control group, the intervention group will show lower intake of calories, total fat, saturated fat, trans fat, cholesterol, sodium, sugars, and unhealthy snacks (i.e., processed snack foods that are not fruits or vegetables), as well as lower intake of their top-3 idiosyncratic unhealthy comfort foods specified at pre-intervention. If participants in the intervention group consume more vegetables or more total fruits, this will be interpreted as evidence for stimulus generalization.

Aim 3: Assess whether experimental condition affects pre- to post-intervention changes in self-reported ratings of fruits on the dimension of pleasantness and intentions to buy fruits in the future.

Hypotheses: Compared to the control group, the intervention group will show a greater increase over time in both pleasantness ratings of fruit and intentions to purchase fruits in the future from pre- to post-intervention.

Aim 4: Test whether experimental condition affects pre- to post-intervention changes in self-reported perceived stress and depressive symptoms.

Hypotheses: Compared to the control group, the intervention group will show greater improvement in perceived stress and depressive symptoms from pre- to post-intervention.

Aim 5: Determine whether any observed effects of experimental condition in Aims 1-4 are moderated by plausible psychological individual difference variables.

Hypotheses: The hypothesized effects in Aims 1-3 above will be greater in individuals who: (1) express greater expectations that eating will improve mood, (2) exhibit higher scores on trait emotional eating, (3) are women (because women tend to report more trait emotional eating than men; Zellner et al., 2006).

Method

Participants

Participants were 100 healthy undergraduate men and women (50% each in each experimental condition) at the University of California, Los Angeles. Although Study 1 included only women because the study was intended as an original proof of concept study and women are more likely to report comfort eating than men (American Psychological Association, 2012; Zellner et al., 2006), Study 2 enrolled both men and women in order to examine gender as a potential moderator of any stress-dampening effects of comfort eating.

I conducted a power analysis to estimate the required sample size to detect an interaction between a between-subjects factor (i.e., experimental condition) and a within-subjects factor (i.e., time, in the context of pre-post measures). G*Power software was used to thus determine the necessary sample size to detect a repeated measures, within-between interaction. As shown in Table 17,

Table 17

Study 2 Sample Size Calculation

	Repeated measures correlation (r)					
	.50		.60		.70	
	Interaction partial eta squared (η_p^2)					
	.02	.06	.02	.06	.02	.06
Power						
.90	132	44	106	36	80	28
.85	112	38	90	32	68	24
.80	**100**	34	80	28	60	22

I estimated the sample size required for several scenarios, specifying various desired power levels (i.e., .80, .85, and .90), estimates of repeated measures correlation between pre-post ratings (i.e., r = .5, .6, and .7), and estimates of the interaction effect between intervention group and time. For the latter estimation, I specified conventional values (Bakeman, 2005) for a small interaction effect size of $\boldsymbol{\eta_p^2}$ = .02, and a medium effect size of $\boldsymbol{\eta_p^2}$ = .06. A sample size of 100 provides power of 0.80 to detect even a small interaction effect between experimental condition and change in food preference ratings over the course of time.

Procedures

Recruitment and pre-screening. Participants were recruited via the psychology department subject pool as well as fliers distributed throughout the university campus. Interested individuals contacted research staff via email, and research staff responded with a link to online pre-screening questionnaires. In the pre-screening, individuals provided information about their demographics and dieting status. They also reported baseline perceived stress and depressive symptoms using the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983), and the CES-D scale (Radloff, 1977), respectively, which were each modified to ask participants about the past 7 days. They also completed a modified version of the aforementioned Food Opinions Survey. This survey asked participants, "What foods would make you feel better if you were stressed? Please list your top three choices." This question was embedded in a series of distractor questions, in which individuals are also asked to rate their top three choices in a series of distractor prompts such as, "What foods would you want if you were on-the-go?" All of these food prompts were presented in free-response format.

Also in pre-screening, participants completed a Food Dimensions Survey, which I adapted very closely from a food evaluation survey used for a conditioning study by Chambers, Mobini, and Yeomans (2007). This survey asked participants to rate a list of 20 fruits, which

were selected based on an assessment of which fruits were available at the grocery stores nearest to the university campus and university undergraduate student housing. For this study, I chose to focus solely on fruits (rather than also including vegetables) for several reasons: (1) I speculated that overall, fruits tend to have greater sugar content than vegetables, and this comparatively higher sugar content could plausibly increase the salience of fruit as a CS, consequently making the conditioning procedure more effective; (2) I aimed to standardize the sugar content of the foods to be conditioned, minimizing variability of sugar content both across foods and between individuals in the experimental and control groups; and (3) an aforementioned meta-analysis conducted by Wang et al., (2014) found that risk of all cause mortality was decreased to a greater extent by each additional daily serving of fruits, compared to vegetables.

In the Food Dimensions Survey, participants first reported whether they had ever tasted each given fruit before (Yes/No). If no, participants did not rate the fruit on any further dimension, and this fruit was not selected for later conditioning. If yes, participants then rated each fruit on five dimensions: familiar, sweet, pleasant, sour, and bitter. In addition to these dimensions adapted from Chambers et al., I also added a sixth dimension, "How likely is it that you will buy this food in the future?" To conduct ratings, participants marked on a 100-point horizontal line (i.e., visual analog scale) anchored from "*not at all*" to "*extremely."*

Then, mirroring the selection process utilized by Chambers et al., the food that was selected for later conditioning for each participant was one that was rated as relatively neutral on the dimension of pleasantness (i.e., between 40-75 on the pleasantness dimension). If a participant rated more than one fruit in this neutral range, the fruit selected for later conditioning was the one that was closest to 50. If multiple fruits were rated close to 50 on pleasantness, then the fruit that was also rated as being the most novel (i.e., lower score on the familiarity dimension) was chosen. As noted by Chambers et al., this selection method offers two important

advantages. First, selection of neutral foods (in terms of pleasantness) avoids confounding of floor or ceiling effects in food ratings. In addition, selection of relatively novel foods minimizes any effects of prior exposure, increasing the food salience and thus, bolstering the ease of Pavlovian conditioning. Furthermore, the more novel the food, the less prior information that participants have learned about it that could compete with new associative learning.

At the beginning of study recruitment, I planned to also only select a fruit for conditioning if it was rated at being quite novel (i.e., < 40 on the familiar rating). However, at pre-screening, most individuals rated most fruits very highly on familiarity (M = 86.09, SD = 13.90 across 371 individuals), which decreased the number of eligible fruits—and in turn, participants—substantially. As a result, this fruit CS requirement was removed to ensure the progress of enrollment.

Lastly, the pre-screening included a run-in task, which is a task that individuals must successfully complete prior to study randomization (Affuso et al., 2014). Here, the task required individuals to complete one 6-minute session of the same PMR activity that they would be completing in their future conditioning trials. This PMR activity was also administered online, and after its completion participants completed a multiple-choice question asking them to identify, “Which of these phrases was included in the recording that you just listened to?” with one correct response and four incorrect responses. This attentional adherence item was used as an eligibility criterion for study enrollment, boosting the likelihood that participants enrolled in the study will adhere to further PMR sessions outside of the lab. Furthermore, this PMR session in pre-screening served another important purpose: the US pre-exposure prior to CS-US conditioning should decrease the likelihood of other unintended CSs in the conditioning context (e.g., the surroundings or the soothing sounds of the PMR vocals) overshadowing learning about the fruit CS. In addition, participants rated how much they liked or disliked engaging in the run-

in PMR activity (1 = *disliked a lot* to 6 = *liked a lot*). Only those who reported some level of liking of the activity (i.e., a score of 4 or higher) were eligible for the study.

Study inclusion criteria were based on ability to carry out the study activities and included: (1) age 18 or older; (2) fluent in English; (3) access to a smartphone with the capacity to connect to the Internet, take pictures, and download apps; (4) reported a neutral pleasantness ranking for a healthy fruit that is in season; (5) reported some level of liking for the PMR activity in pre-screening; and (6) exhibited a moderate to high level of chronic stress for their gender on the 10-item PSS (Cohen et al., 1983).

Eligible women scored 13 or higher on the PSS-10 scale, and eligible men scored 10 or higher. These cutoffs were determined using prior research in 557 U.S. college students, which found that college women and men exhibit mean PSS-10 scores of 18.17 (*SD* = 6.13) and 15.83 (*SD* = 6.53), respectively (Smith, Rosenberg, & Haight, 2014) . These mean levels were conceptually considered to represent moderate stress. To then determine the lower threshold for moderate stress for each gender, the standard deviations were subtracted from these means scores and then rounded up to the nearest whole number. Only those with moderate to high chronic stress levels were enrolled in the study, so that when participants engaged in the conditioning trials, they would already have some level of life stress to be reduced.

Exclusion criteria were chosen based on incompatibility with the study methods and included: (1) responded incorrectly to the pre-screening PMR attentional adherence item; (2) current strict dieting; (3) history of substance abuse or eating disorder; (4) current diagnosis of a psychiatric condition; (5) metabolic or endocrine disorder; (6) current major illness or injury; (7) allergic to all the fruit options for conditioning trials; or (8) did not rate any fruits that were currently in season as a 40-75 on the pleasantness scale.

Stimuli and Responses. This research followed the principles of Pavlovian conditioning: The CS was each participant's respective assigned fruit, and the experimenter selected a fruit idiosyncratic to each individual, as described above. The US was Progressive Muscle Relaxation, and the UR was psychophysiological stress relief. I expected that repeated temporal CS-US pairing would cause the CS (fruit) alone to elicit a CR of psychophysiological stress relief.

Progressive Muscle Relaxation. As discussed previously, a well-established body of literature has shown that a brief PMR activity decreases perceived stress and anxiety (Carlson & Hoyle, 1993), in addition to decreasing SNS activation (King, 1980). Thus, I chose to use PMR as the US in this study. In order to ensure that PMR induces psychophysiological stress relief in UCLA students, I conducted two pilot studies in healthy young men and women at UCLA, wherein participants reported the extent to which they felt four emotions (1 = *not at all* to 7 = *extremely*), both at baseline (pre-PMR) and immediately post-PMR.

Pilot study 1. In the first pilot study in 30 participants (22 female), the PMR recording used was 15-minutes long in total. As hypothesized, comparing reported emotion from pre-post PMR, over time participants reported decreases in the extent to which they felt tense (from M = 2.27, SD = 1.12 to M = 1.43, SD = .57; p = .001) and stressed (from M = 2.57, SD = 1.14 to M = 1.70, SD = .99; $p < .001$). In parallel, over time participants reported increases in the extent to which they felt relaxed (from M = 4.80, SD = 1.45 to M = 6.17, SD = 1.26; $p < .001$) and calm (from M = 4.53, SD = 1.72 to M = 6.03, SD = 1.40; $p < .001$). Moreover, participants showed a decrease in heart rate from pre-PMR (M = 74.78, SD = 10.83) to the last 2 minutes of PMR (M = 71.86, SD = 12.98), p = .041. These observed effects of PMR on psychophysiological outcomes provided preliminary evidence that PMR is an appropriate technique for eliciting stress reduction in the present study's desired population.

Pilot study 2. To minimize participant burden in Study 2, I conducted a second pilot study in 25 participants (20 female) to determine whether an abbreviated PMR recording (i.e., 6 minutes total) would also be effective in reducing these same psychophysiological stress measures. This abbreviated recording removed sections involving the tensing of body parts that would be noticeable in public places (e.g., forehead, shoulders), with the aim of boosting adherence. This pilot also compared two versions of the PMR recording, with one recording narrated by a female, and one narrated by a male. Participants were randomly assigned to either the male or female narrator.

Results from one-way, between-subjects ANOVAs revealed that compared to the male narrator, the female narrator's voice was rated as significantly more calming (M = 5.15, SD = 1.14 vs. M = 3.71, SD = 0.91; $p < .001$); more likeable (M = 4.15, SD = 1.35 vs. M = 2.93, SD = 1.14; $p = .017$); and easier to listen to (M = 5.08, SD = 1.26 vs. M = 3.93, SD = 1.07; $p = .017$); therefore, only the female narrator's voice was used in Study 2.

Importantly, this 6-minute PMR recording with a female narrator was also effective in reducing psychophysiological stress. Comparing reported emotion from pre-post PMR, over time participants reported decreases in the extent to which they felt tense (from M = 3.23, SD = 0.44 to M = 2.62, SD = 0.29; $p = .025$) and stressed (from M = 3.85, SD = 0.41 to M = 2.92, SD = 0.42; $p = .002$). Furthermore, over time participants reported increases in the extent to which they felt relaxed (from M = 4.00, SD = 0.47 to M = 5.23, SD = 0.36; $p = .002$) and calm (from M = 4.08, SD = 0.49 to M = 5.62, SD = 0.29; $p = .002$). Finally, participants showed a significant decrease in heart rate from pre-PMR (M = 76.15, SD = 15.87) to the fifth minute of the PMR (M = 74.67, SD = 15.68), $p = .047$. Therefore, these results collectively indicate that the brief PMR effectively reduced psychophysiological stress from baseline to 5-6 minutes later.

Finalized Study 2 recordings. A total of eight 6-minute PMR recordings were created and administered in Study 2. Although all recordings included tensing of the same four body parts (i.e., left and right fists and thighs), the order in which the muscles were tensed was counterbalanced, with half the recordings starting with the fists, and half starting with the thighs. Furthermore, four different tones were included in the recordings, with each tone occurring one time in two of the recordings. The tone in each recording served either to cue participants to begin eating (intervention group), or served as a control tone (control group). All participants were exposed to all eight recordings (the first in pre-screening, and the rest during the first week of study participation). The order of body part tensing and the use of four different tones served to minimize the possibility of one particular body part or cuing tone from becoming an additional CS that could otherwise compete with the fruit CS and deter the desired formation of fruit-stress reduction associations.

Study Design. In a 7-day intervention, eligible participants were randomly assigned to one of two conditions: (1) an intervention group, wherein an initially neutrally-liked healthy fruit (CS) was repeatedly temporally paired with stress reduction (US) that is known to elicit decreased psychophysiological stress (UR); or (2) a control group, wherein participants also repeatedly received the same CS and US, but these stimuli were explicitly unpaired and thus never overlapped temporally. I term the temporally overlapping trials used in the intervention group *paired trials*, whereas I term the non-temporally overlapping trials used in the control group *unpaired trials*. The intervention group completed seven paired trials, and the control group completed seven unpaired trials.

Trial locations. For all participants, the first trial of the intervention took place in the laboratory. Once per day on the six consecutive days after participants' first laboratory visit, participants completed either an additional daily paired trial (intervention group) or an additional

daily unpaired trial (control group). Thus, in total, both the intervention and control group received both the CS and US once per day, in either a paired fashion (intervention group) or unpaired fashion (control group). As outlined in Table 18, two of the seven total trials were administered in the lab (on days 1 and 4), whereas the remaining five trials were administered outside of the lab (on days 2, 3, 5, 6, and 7). All lab visits took less than 1 hour, and all activities outside of the lab took less than 20 minutes per day.

Table 18

Location and Outline of Study 2 Activities by Day

Day #	**In Lab**	**Outside Lab**	**Activities**
0		X	Pre-screening surveys (PSS, CESD, food ratings)
1	X		Trial 1, fruit kit
2-3		X	Trials 2-3
4	X		Trial 4, fruit kit
5-7		X	Trial 5-7
8	X		Fruit CS intake, ANS & mood changes, PMR survey
11-14		X	Daily food diaries & surveys
15		X	Post-intervention surveys (PSS, CESD, food ratings)

Note. According to randomization, participant trials were either paired or unpaired

All food for trials was provided for all participants. Before participants left their first lab visit, research staff provided them with a fruit kit containing 2 servings of their assigned fruit, so that they could complete their next two trials over the course of the next two days outside of the laboratory. Similarly, before participants left their second lab visit, the experimenter provided them with another fruit kit containing 3 servings of their assigned fruit, so that they could complete the remaining trials outside of the laboratory. In order to avoid any fresh fruits passing their ideal ripeness or perishing before their respective trials, participants were given no more than 3 servings per fruit kit. Any fruits that were not in season during a given month were not selected as the fruit CS for any participants during that month.

Paired trial composition. Figure 8 outlines the order of events making up each paired trial for intervention group participants. For those trials taking place in the laboratory, immediately before the trials took place, intervention group participants were given a serving of their assigned fruit (CS), which was set aside. Participants began each trial by engaging solely in the PMR activity, alone in a private room with dimmed lighting. Near the end of the PMR activity (i.e., after 5 of the 6 total minutes of the recording had elapsed), participants were cued by a tone to begin consuming their fruit. For the first minute that participants were eating, they also continued to listen to the PMR recording. However, importantly, during this last minute of the recording, the audio content shifted to focus more on guided imagery, and did not instruct participants to tense muscle groups, which could otherwise impede eating. That is, the remainder of the recording provided thought guidance that no longer involved muscle tensing (e.g., "And you can notice how serene and easy it is in your place of relaxation…calm and good and peaceful…and you can be aware of how you feel refreshed and relaxed…").

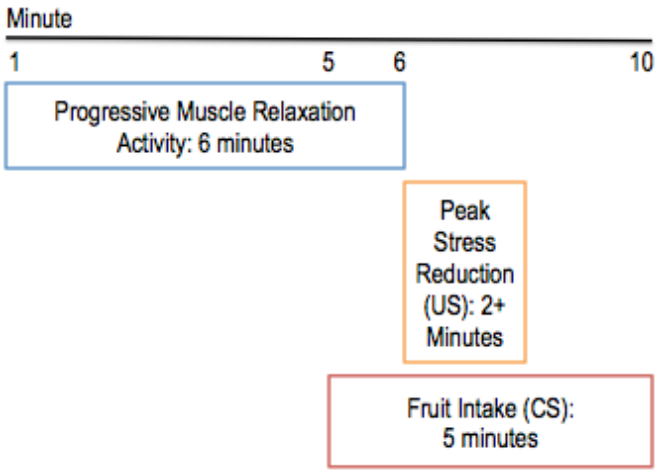


Figure 8. Timeline of paired trials in Study 2

After participants had been eating for approximately 1 minute with the recording, the recording ended and participants were assumed to be entering a state of peak stress reduction induced by the PMR activity. This assumption is based on the aforementioned PMR pilot data evidencing PMR-induced psychophysiological stress relief.

For paired trials taking place outside of the laboratory, the above protocol was very similar, but altered in a few ways. The experimenter instructed participants on how to complete

the paired trials outside of the laboratory online using Qualtrics via an electronic device. The online Qualtrics method of delivering the PMR permitted the monitoring of adherence to the paired trials, and participants were informed that their Qualtrics data would be reviewed daily. Paired trials were considered to be on time for a given day if they were completed before 4:00AM on the following day. To check for adherence to fruit consumption, the experimenter instructed participants on how to submit before and after photos of the fruit when completing paired or unpaired trials. For example, participants assigned to consume pears took a "before" photo of the whole pear, and an "after" photo showing just the core of the pear. Similarly, a "before" photo of a clementine included the whole or uneaten fruit, whereas an "after" photo included the peels of the clementine post-consumption. This digital photography methodology accurately estimates food intake in many environments and reduces participant burden (Martin et al., 2014). Participants were also encouraged to take a screenshot of their photos on their phones so that research staff could confirm the date and time that the photos were taken.

Participants were instructed to vary the location (e.g., in a dorm room, at a dining hall, on campus) and time (e.g., morning, afternoon, evening) of the trials conducted outside of the lab. Participants were instructed to complete the activities any time of day from waking to bedtime. As noted previously, it is important to vary the context of the trials, so that participants do not learn that the CS-US association only applies to a single context (Savastano & Miller, 1998). In addition, participants were told that they were only to eat the fruit while they were completing paired trials – not during their regular eating. Participants were also encouraged to complete the trials at times when they were feeling stressed. Lastly, participants were instructed to have the fruit nearby and ready for consumption from the start of the PMR activity. The PMR recording had a tone that rang at the appropriate time when participants should begin eating, and participants were instructed to begin eating upon hearing this tone.

Nonpaired control trial composition. Following the same fruit assignment process as the intervention group, participants in the control group were also be assigned to consume a fruit that was idiosyncratic to each participant. The procedure for the control group was the same as that of the intervention group, except for one crucial difference: participants in the control group did not experience temporal overlap between CS (fruit) and US (stress reduction) administration. Instead, participants were assigned to consume the fruit sometime in the morning (i.e., any time after waking and before 1:30PM), and to engage in the PMR activity (to elicit stress reduction) in the evening (i.e., any time after 5PM and before going to bed). For unpaired trial days taking place in the laboratory (days 1 and 4), control participants performed half of the trial in the lab in the morning (CS fruit exposure) and half of the trial later in the evening (US stress reduction exposure). Adherence to the PMR and food consumption outside of the lab was monitored using the same methods as for the intervention group.

Laboratory visit 1/baseline. Before eligible participants arrived for the first lab visit, they were instructed to refrain from eating in the 3 hours prior. The purpose of this fasting period was to increase the salience and biological relevance of the CS (fruit). Following a hunger adherence procedure used in a prior study by Chambers et al. (2007), participants were told that they were required to produce a saliva sample at the start of their lab visit, which would confirm whether they have indeed been fasting for the past 3 hours. Although these saliva samples were indeed be collected, they were not analyzed, and were instead solely used as an added motivation for participants to adhere to the fasting protocol. Similarly, for trials occurring outside of the lab, participants were told to refrain from eating for the 3 hours before fruit consumption, and to take a saliva sample either immediately before fruit consumption, so that the experimenter could then confirm fasting adherence (which was also not actually analyzed).

During the consent process, the experimenter told participants the following cover story about the purpose of the study: “The aims of the study are to understand how feelings of relaxation affect nutrient uptake, physiology, and well-being. Specifically, we will assess how a 1-week intervention of brief relaxation activities affects nutrient uptake from fruits (as indicated by the daily saliva samples), both during a week of the intervention, and near the end of the week after the intervention. Additionally, we will measure autonomic nervous system activity to assess any effects of the intervention on physiological functioning. For standardization purposes, you will be given the same food to eat each day. The food diaries will help us understand effects of the intervention on a broader range of foods and nutrients.”

Consenting participants then provided the aforementioned saliva sample. Next, participants in intervention group completed their first paired trial. Participants in the control group completed the first half of their unpaired trial (fruit consumption) in the lab, and completed the second half of the trial (PMR-induced stress reduction) later that evening outside of the lab. Lastly, the experimenter gave participants detailed written and verbal instructions on how to conduct the trials outside of the lab over the next few consecutive days.

Laboratory visit 2/trial 2 and fruit kit provision. The second lab visit took place on Day 4. Upon arrival, the experimenter asked participants how they were doing with the activities outside of the lab, and if participants reported any concerns or difficulties, the experimenter noted them and also clarified trial information to assist with adherence. Then, participants provided a saliva sample. Next, intervention group participants completed a paired trial, and control group participants completed half an unpaired trial (fruit only), with the second half (PMR) taking place later that evening outside of the lab. Lastly, a second fruit kit with 3 servings of each participant’s idiosyncratic fruit was provided for the remaining 3 trials outside of the lab.

Laboratory visit 3/primary outcome assessment. A third and final laboratory visit took place on the day after each participant's final trial (Day 8). This timing was chosen in order to assess the effects of the conditioning on stress at the time when the conditional responding was expected to be the strongest (i.e., in very close proximity to the final paired trial).

First, participants provided an adherence saliva sample. Next, the experimenter attached participants to non-invasive sensors and equipment to assess heart rate variability (via electrocardiography) and electrodermal activity, which was captured continuously throughout the duration of the lab visit. Participants were told to sit with their legs and ankles uncrossed with their feet flat on the floor to avoid postural influences on ANS data collection. Before baseline ANS measurements were taken, participants were given 3 minutes to sit and relax to become accustomed to the sensation of having physiological equipment on the body. Then, baseline ANS activity was captured for 3 minutes. During these 3 minutes of baseline ANS assessment, participants also completed a baseline PANAS mood state questionnaire (Watson, Clark, & Tellegen, 1988), as well an assessment of hunger and the last time food was consumed.

After these baseline measurements, participants remained seated in the room and the experimenter provided them with 2 servings of their idiosyncratic fruit CS from their prior paired or unpaired trials. Participants were given 5 minutes to consume at least 1 serving of the fruit, and were invited to help themselves to the second serving if they would like. Unbeknownst to participants, the experimenter recorded the weight of the food dishes both before and after the participant had the opportunity to eat.

Immediately after eating, the experimenter removed the food from the room and ANS activity was again assessed for 3 minutes while participants remain seated and completed several questionnaires. Participants first completed PANAS 2, followed by a PMR exit questionnaire. Then, the experimenter then detached all physiology equipment.

Next, the experimenter instructed participants on how to complete food diaries outside of the lab via the free smartphone app MyFitnessPal. After the home food monitoring was explained and participants had the opportunity to ask any questions about this procedure, the experimenter measured participants' height and weight, which concluded the visit.

Food diaries. On 4 consecutive days (Days 11-14), participants were instructed to use the MyFitnessPal smartphone app to record their complete food intake throughout the course of each day. The 4 days included two weekdays (i.e., Friday and Monday) and 2 weekend days (i.e., Saturday and Sunday). The experimenter set up participants' login ID and password prior to the final lab visit and removed default settings about weight loss and monitoring, as well as social media sharing. Participants were instructed to only track food and beverage intake – they were not to engage with the MyFitnessPal community or track exercise or weight.

At the end of each diary day, participants also took one saliva sample and completed a Brief Diary Survey about their day online. Participants rated how stressful their day was (1 = *not all* to 7 = *extremely*) and reported the time of day when they felt most stressed. Several distractor items were also included. Participants were given written instructions for how to complete the diaries. The experimenter sent participants an email reminder in the morning on each diary day to remind them to complete their food log, daily diary survey, and saliva sample.

Post-intervention questionnaire assessment. On Day 15 (i.e., the day after the final daily food log and diary), participants were emailed a link to the post-intervention questionnaire assessments for the modified Food Opinions Survey, as well as the Food Dimensions Survey, which included the same list of 20 fruits from pre-intervention along the same six dimensions: familiar, sweet, pleasant, sour, bitter, and likeliness of purchasing the food in the future. Additionally, participants completed post-intervention assessments of perceived stress (Perceived Stress Scale; Cohen, 1983) and depressive symptoms (CES-D; Radloff, 1977) during

the past 7 days. Then, participants completed surveys for two moderators: a measure of trait emotional eating (van Strien et al., 1986) and the Comfort Eating Expectations Scale that I created previously in Study 1. Finally, debriefing information was provided online and participants were compensated with either course research credit or $50.

Measures

Appendix C, Appendix D, and Appendix E contain the measures from Study 2 pre-questionnaires, lab day questionnaires, and post-intervention home questionnaires, respectively.

Measures collected at pre-screening only.

Demographic information. Participants self-reported the following information, which was used to determine eligibility: age, fluency in English, access to a smartphone with the ability to connect to the Internet and download apps, history of eating disorder or substance abuse, dieting status, current major illness or injury, and current diagnosed psychiatric condition. The following self-reported variables were used to characterize the sample: gender, racial/ethnic heritage, family income while growing up, and subjective social status as assessed via the MacArthur Scale of Subjective Social Status-Youth Version (Goodman et al., 2001).

Progressive muscle relaxation adherence. To check whether individuals actually completed and paid attention to the PMR activity in pre-screening, they were asked a single-item of, “Which of these phrases was included in the recording that you just listened to?” with one correct response.

Measures collected both at pre-screening and at Day 15.

Food dimension ratings. As described above, this scale was adapted from Chambers et al., (2007), and participants rated 20 fruits on the dimensions of familiar, sweet, pleasant, sour, bitter. A sixth dimension adapted from Bratanova, Loughnan, Klein, Classen, and Wood (2016) assessed likelihood to purchase the fruit in the future. All items were rated on each dimension

using a 100-point visual analog scale, following the example of Chambers et al.

Food opinions. The modified Food Opinions Survey (Wagner et al., 2014) was described in detail in Study 1.

Perceived stress. The 10-item Perceived Stress Scale (PSS) was modified to measure perceived stress in the past 7 days (Cohen et al., 1983).

Depressive symptoms. The Center for Epidemiological Studies Depression Scale was modified to measure depressive symptoms in the past 7 days (Radloff, 1977).

Measures collected at lab visit 3.

Hunger. Hunger was assessed with the item, "How hungry are you feeling right now?" (1 = *not at all* to 7 = *extremely hungry*)" Participants also reported the last time that they had something to eat.

Mood. Positive and negative mood were assessed at 3 time points during the final lab visit using the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). In addition to the 20 emotion items from the original scale, the survey also included the items "sad," "happy," "stressed," "calm," "tense," and "relaxed" in their relevant positive or negative subscales.

***Progressive muscle relaxation acceptability*.** I created this 7-item measure assessing participants' perceptions of acceptability and burden related to the PMR activity. Sample items include: "This activity was easy to incorporate in my daily routine," "This activity made me feel relaxed," and "I would recommend this activity to others," on a scale from 1 = *not true at all* to 6 = *extremely true.* The negatively framed item was reverse coded and all item responses were averaged to create an overall acceptability rating for the PMR activity.

Anthropometrics. Weight and height were recorded and used to compute BMI. BMI was incorporated as a covariate for later analyses that include ANS outcomes.

Electrodermal activity and heart rate variability. To measure EDA and HRV, Study 2 used the same configuration of sensors, wireless transmitters, hardware, and software as described for Study 1. EDA was used as an index of SNS activation, and RMSSD was used as an index of HRV and PNS activation. To correct for normality, prior to hypothesis testing, HRV scores were log transformed, and EDA scores were square root transformed. One participant with negative EDA scores was omitted from analysis.

To capture the fast response of EDA and HRV, I analyzed three time periods of interest: the last minute of baseline, the first minute during CS fruit intake, and the first minute immediately after CS fruit intake. Each segment of data was scored using MindWare software.

MyFitnessPal scoring. MyFitnessPal produced automated output data about users' intake in terms of calories, total fat (g), saturated fat (g), trans fat (g), cholesterol (mg), sodium (mg), dietary fiber (g), and sugars (g).

Food logs were reviewed by both a research assistant and myself in order to calculate intake of participants' idiosyncratic fruit CS, as well as fruits, vegetables, unhealthy snacks, and unhealthy comfort foods. Prior to food log review, I consulted with a registered dietician to establish guidelines and criteria for determining which foods would be considered fruits, vegetables, and unhealthy snacks. I then trained research assistants in implementing these guidelines before beginning food log scoring. An average daily intake was calculated for fruit CS, fruits, and vegetables. Unhealthy snacks and unhealthy comfort foods were each summed to compute the total number of instances in which the food type was consumed across the 4 days.

Fruits and vegetables. To calculate the amount of fruits and vegetables consumed in cups, the publicly available online dietary tool Super Tracker was used (**www.supertracker.usda.gov**). Provided by the United States Department of Agriculture, this tool is informed by United States federal government's national dietary guidelines

(www.ChooseMyPlate.gov). In general, 1 cup of fruit was then considered to equate to 1 serving of fruit, and 0.5 cup of vegetables translated to 1 serving of vegetables (with the exception of leafy vegetables such as lettuce, for which 1 cup translated to 1 serving). Starchy vegetables such as fried potatoes, corn, and peas were not counted as vegetables (citation). In addition, no beverages (other than fruit juices) were quantified for analysis, unless they were in in somewhat solid form (e.g., smoothies containing whole fruit or vegetable ingredients).

Unhealthy snacks. Unhealthy snacks included processed foods typically thought of as unhealthy snacks or desserts (e.g., chips, ice cream, candy, chocolate), regardless of whether the participant listed them as a snack or as part of a meal. Unhealthy snacks also included foods listed by the participant as a snack that contained substantial amounts of added sugar or salt (e.g., instant ramen); and dairy products that were not reduced fat (e.g., cheese, whole milk, yogurt).

Unhealthy comfort foods. I also calculated the number of times that participants consumed one of their top three idiosyncratic comfort foods reported in pre-screening. If two different types of the same comfort food were consumed as a part of the same meal or snack (e.g., two different types of sushi rolls within the same meal), they were counted jointly as one instance of consuming the comfort food.

Questionnaire collected at Days 11-14. One brief 5-item survey asked participants to report how stressful their day was, and at what time they were feeling most stressed. Three distractor questions asked participants to report how tired they felt that day, how enjoyable their day was, and how many hours of sleep they got on the previous night.

Measures collected at Day 15 only.

Comfort eating expectations. The refined 5-item Comfort Eating Expectations Scale assessed the extent to which participants believe that food improves their mood.

Trait emotional eating. Trait-like emotional eating was measured using the Dutch Eating

Behavior Questionnaire (van Strien et al., 1986), as described above in Study 1.

Free response exit items. Participants were asked via free response what they liked and disliked about the study, what they would change about the study to make participation more enjoyable for future participants, what their ideas were (if any) about what the researchers were expecting to find, and what (if anything) they were suspicious about that happened in the study.

Statistical Analysis

Multilevel analysis for physiological outcomes was conducted using SAS University Edition software (version 9.4, SAS Institute, USA). All other analyses were conducted using SPSS software (version 24.0, IBM, USA). Statistical significance was set at $p < .05$.

Food diary outcomes. ANOVA tests were used to test for effects of condition on each dietary food log outcome. To test for moderation of these effects, the MODPROBE statistical macro (Hayes & Matthes, 2009) was used to examine 2-way interactions between experimental group and each moderator of interest (entered as a continuous variable).

Mood, perceived stress, depressive symptoms, and food ratings. Repeated measures ANOVA tests were used to test for effects of condition on the outcomes that were collected at 2 time points: negative mood, positive mood, perceived stress, depressive symptoms, and ratings of fruit CS pleasantness and likelihood to buy. To test for moderation of these effects, each moderator was added to these repeated measures ANOVA tests to examine 3-way interactions between group, time, and each moderator of interest (entered as a continuous variable).

Physiological outcomes. Multilevel modeling was used to test hypotheses involving HRV and EDA, as these outcomes involve three repeated measures, and this statistical method is appropriate for modeling data with repeated measures nested within individuals. Like other prior research (Croswell et al., 2017), this study included age and BMI as covariates in all analyses of

HRV and EDA, as these factors can influence physiological outcomes.[4] Each multilevel model that examined main effects of condition included effects of experimental group, time, and the group by time interaction. To examine moderation of these effects, additional multilevel models were specified to examine 3-way interactions between experimental group, time, and each moderator of interest (entered as a continuous variable).

Probing interactions. To follow up on significant 3-way interactions, the Group x Time 2-way interaction was tested separately at high and low levels of the moderator, determined by median split. If the 2-way interaction was non-significant in both groups ($p > .05$), the moderation was not probed any further or interpreted as significant.

Results

Adherence

Figure 9 displays a CONSORT (Consolidated Standards of Reporting Trials) flow diagram (Moher, Schulz, Altman, & Concort Group, 2001) for the study, including details about participant enrollment, allocation, follow-up, and analysis. Participants who completed 5 out of 7 (~71%) of their week 1 trials (Days 1-7) perfectly were included in data analysis. A perfect trial constituted the submission of surveys and photos on time (Days 2, 3, 5, 6, 7), or successful completion of a lab visit (Days 1 and 4). Adherence to the trials was high, with 100 of the 116 participants who started the study (86.21%) completing 5 or more perfect trials. On average, the intervention group completed more of their trials perfectly ($M = 6.54$, $SD = 0.68$; $Mdn = 7$; $Mode = 7$) than the control group ($M = 5.76$, $SD = 0.77$; $Mdn = 6$; $Mode = 5$).

[4] Results of tests of main effects on physiological outcomes remained the same regardless of whether age and BMI were included as covariates.

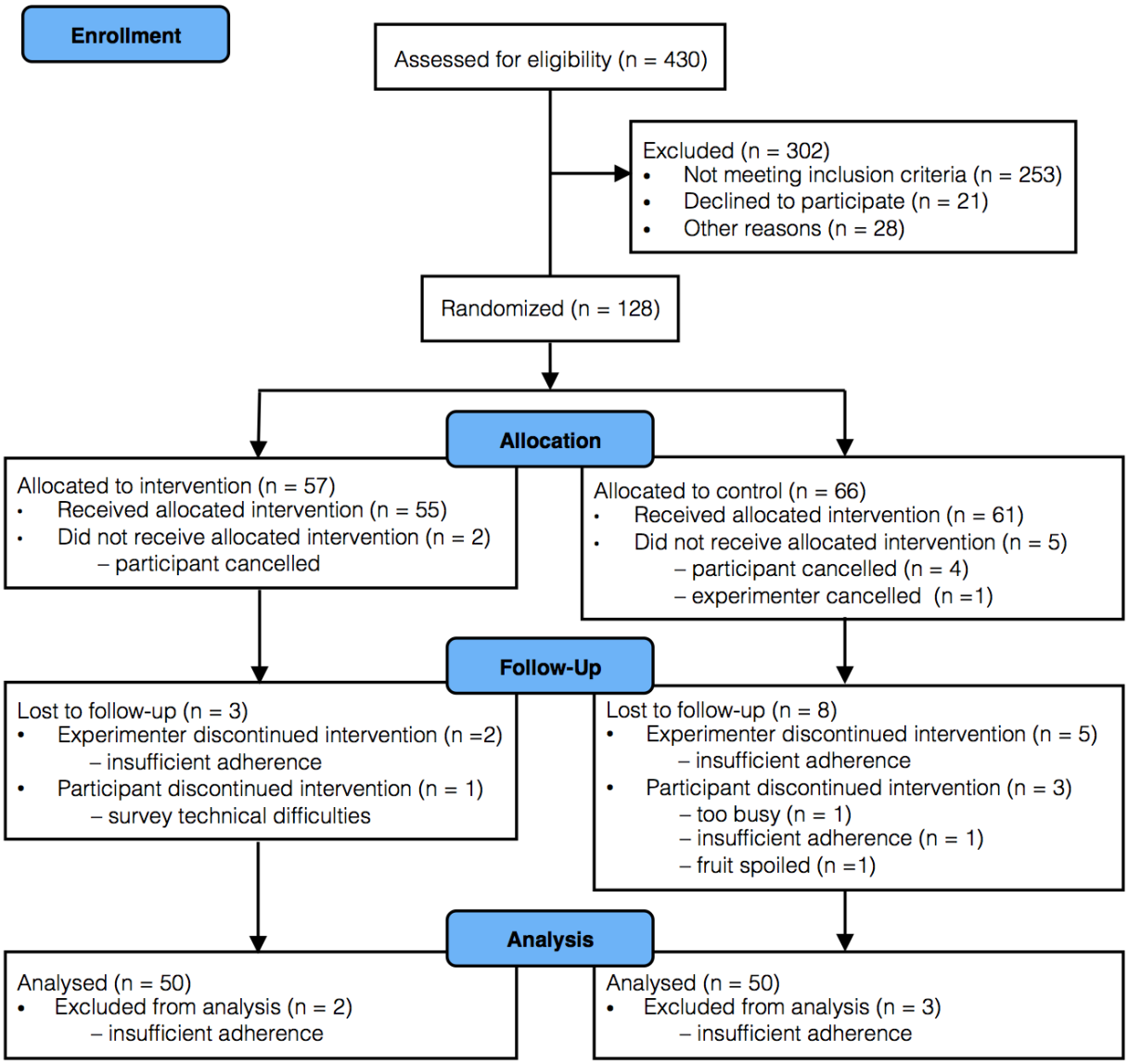


Figure 9. Study 2 CONSORT flow diagram including details about enrollment, allocation, follow-up, and analysis. A total of 5 individuals were eligible for the study and scheduled for laboratory visits, but elected to cancel their participation before their first visit. Information is not available regarding which condition these 5 individuals had been initially randomized to, and therefore they are excluded from the allocation boxes.

Participant Demographics

Table 19 presents descriptive statistics for the 100 participants (74 female) who were analyzed in hypothesis testing. The median family income for the sample was $80,000-89,999.

Table 19

Study 2 Sample Demographics

Characteristic	***n***	***M* (*SD*) or %**	**Min-Max**
Age	100	20.65 (4.63)	18-50
Race/ethnicity	100		
Asian, Asian American, Pacific Islander	43	43	
White/Anglo or European American	24	24	
Hispanic/Latino(a)	18	18	
Bi-racial	6	6	
Arabic/Middle Eastern	4	4	
Black/African American, Caribbean	4	4	
Other	1	1	
Family income	100		
Less than $10,999	2	2	
$10,000 - $19,999	3	3	
$20,000 - $29,999	7	7	
$30,000 - $39,999	7	7	
$40,000 - $49,999	7	7	
$50,000 - $59,999	9	9	
$60,000 - $69,999	6	6	
$70,000 - $79,999	6	6	
$80,000 - $89,999	6	6	
$90,000 - $99,999	9	9	
$100,000 - $124,999	15	15	
$125,000 - $149,999	7	7	
Over $150,000	16	16	
Subjective social status (school)	100	6.86 (1.66)	1-10
Trait emotional eating (DEBQ)	100	2.49 (0.79)	1-5
Comfort eating expectations	100	3.78 (1.02)	1.60-6.00
Body Mass Index	100	23.81 (3.66)	17.20-39.02

Note. DEBQ = Dutch Eating Behavior Questionnaire.

PMR and Fruit CS Acceptability

Day 8 PMR acceptability. Table 20 displays acceptability data collected on Day 8 regarding the PMR activity. Overall, participants reported that they completed the PMR activity the number of times that they were instructed to, which is consistent with the fact that the final sample of participants only included those who completed at least 71% of their trials perfectly.

Notably, on average, participants reported that they enjoyed engaging in the PMR activity and that it made them feel relaxed. In addition, participants did not feel that the PMR took too much time out of their day, and they found the activity to be easy to incorporate into their daily routine. Finally, participants reported that they would use the activity as a stress reduction technique in the future and that they would recommend it to others.

Table 20

Study 2 Progressive Muscle Relaxation Acceptability

Item	**Entire Sample** ***M* (*SD*)**	**Intervention Group** ***M* (*SD*)**	**Control Group** ***M (SD)***	**Test** ***p***
"I enjoyed engaging in this activity."	4.11 (1.15)	3.92 (1.09)	4.30 (1.18)	.097
"I would recommend this activity to others."	4.11 (1.41)	3.84 (1.30)	4.38 (1.48)	.056
"This activity took too much time out of my day."	1.63 (0.81)	1.74 (0.85)	1.52 (0.76)	.177
"This activity was easy to incorporate in my daily routine."	4.06 (1.36)	4.00 (1.25)	4.12 (1.48)	.662
"This activity made me feel relaxed."	4.42 (1.22)	4.04 (1.05)	4.80 (1.26)	.001
"I would use this activity as a stress reduction technique in the future."	4.00 (1.52)	3.62 (1.43)	4.38 (1.52)	.012
"I completed this activity the number of times that I was instructed to."	5.75 (0.74)	5.88 (0.52)	5.62 (0.91)	.080

Note. Items were rated on a scale from 1 = *not true at all* to 6 = *extremely true.*

Day 15 free response exit items. Some participants did not report enjoying the PMR or their fruit CS. In the final survey, 14 participants reported via free response that they either did not enjoy the PMR or felt that it was too repetitive. In addition, 22 participants reported that they either didn't like their fruit CS very much, that it turned sour-tasting or went bad over time, that they got tired of eating it for several days in a row, or that they believed that the study could be improved by allowing participants to choose their own fruit because there may be another one they may like better. Finally, 10 participants reported that they didn't particularly enjoy fasting for 3 hours prior to fruit intake, and a greater number of intervention (n = 9) than control participants (n = 1) reported this, $F(1, 98) = 7.50$, $p = .007$. When the 41 participants who made such comments regarding the PMR, fruit, or fasting were removed from analysis, the results for main effects tests in Aims 1-4 remained the same as when all 100 participants were included.

Fruit CS. The provided fruit CS were: pomegranate (n = 16); apples and bananas (n = 11 each); blueberries, honeydew, pears, and pineapples (n = 9 each), oranges (n = 7); grapes (n = 6); clementines (n = 4), apricots (n = 3), strawberries (n = 3), mangos (n = 2), and kiwi (n = 1). No participants received cantaloupe, cherries, nectarines, peaches, plums, or star fruit.

Aim 1. Does post-intervention fruit CS intake reduce psychophysiological stress?

At the start of the final lab visit wherein the acute effects of fruit CS intake were examined, participants reported a moderate level of hunger (M = 4.22, SD = 1.49).

Negative mood. In the overall sample, fruit CS consumption reduced negative mood from baseline (M = 20.29, SD = 5.76) to post-consumption (M = 16.93, SD = 4.76), $F(1,98)$ = 103.84, $p < .001$, $\eta_p^2 = .514$. As shown in Figure 10, this effect differed by condition, $F(1,98)$ = 4.01, p = .048, $\eta_p^2 = .039$. Specifically, those in the intervention group showed a greater decrease in negative mood over time (from M = 21.24, SD = 6.56 to M = 17.22, SD = 5.57) than the control group (from M = 19.34, SD = 4.72 to M = 16.64, SD = 3.82). The two groups were not significantly different in negative mood at baseline, $F(1,98)$ = 1.07, p = .30.

Positive mood. In the overall sample, fruit CS intake also increased positive mood from baseline (M = 34.00, SD = 8.50) to post-consumption (M = 35.10, SD = 9.86), $F(1,98)$ = 5.14, p = .026, $\eta_p^2 = .05$. However, as shown in Figure 11, this effect did not differ between the intervention group (change from M = 33.12, SD = 7.81 to M = 33.72, SD = 10.30) and the control group (change from M = 34.88, SD = 9.13 to M = 36.48, SD = 9.30), $F(1,98)$ = 1.06, p = .31.

Physiological outcomes. Table 21 presents change in HRV and EDA by condition across the three time points: baseline, during fruit CS intake, and immediately post-fruit consumption. Figures 12 and 13 also present changes over time in HRV and EDA, respectively.

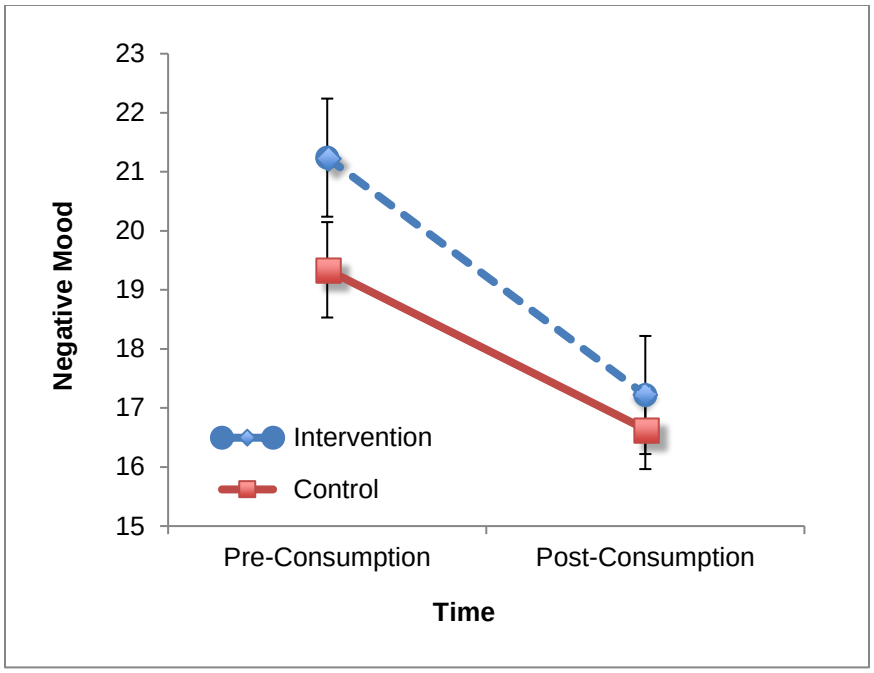


Figure 10. Negative mood response to fruit CS intake in Study 2. Values represent scores on the negative mood subscale of the Positive and Negative Affect Schedule. Error bars represent standard errors.

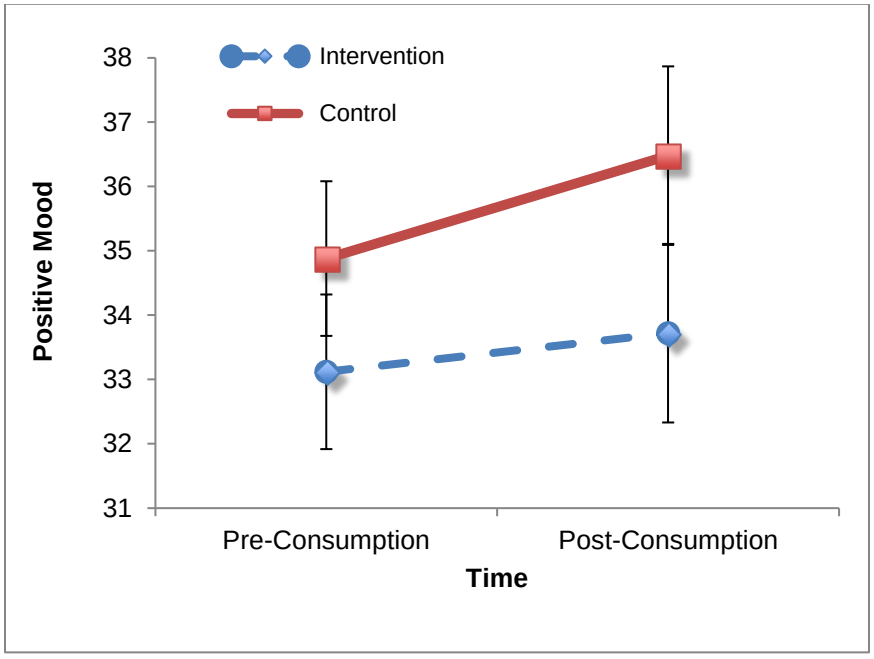


Figure 11. Positive mood response to fruit CS intake in Study 2. Values represent scores on the positive mood subscale of the Positive and Negative Affect Schedule. Error bars represent standard errors.

Table 21

Study 2 Physiological Response to Fruit CS Intake by Condition

Outcome	Baseline *M* (*SD*)	Fruit Intake *M* (*SD*)	Immediately Post- Food Intake *M* (*SD*)
RMSSD (ms)			
Intervention	52.47 (32.76)	50.00 (44.63)	62.55 (46.42)
Control	46.88 (26.15)	43.64 (28.91)	53.19 (32.66)
EDA			
Intervention	9.55 (6.55)	9.53 (6.71)	8.31 (5.74)
Control	10.60 (7.59)	10.64 (7.32)	10.44 (7.69)

Note. Raw values are presented here. Transformed values were used in all analyses. RMSSD = root mean square of the difference of successive R-R intervals; PEP = pre-ejection period.

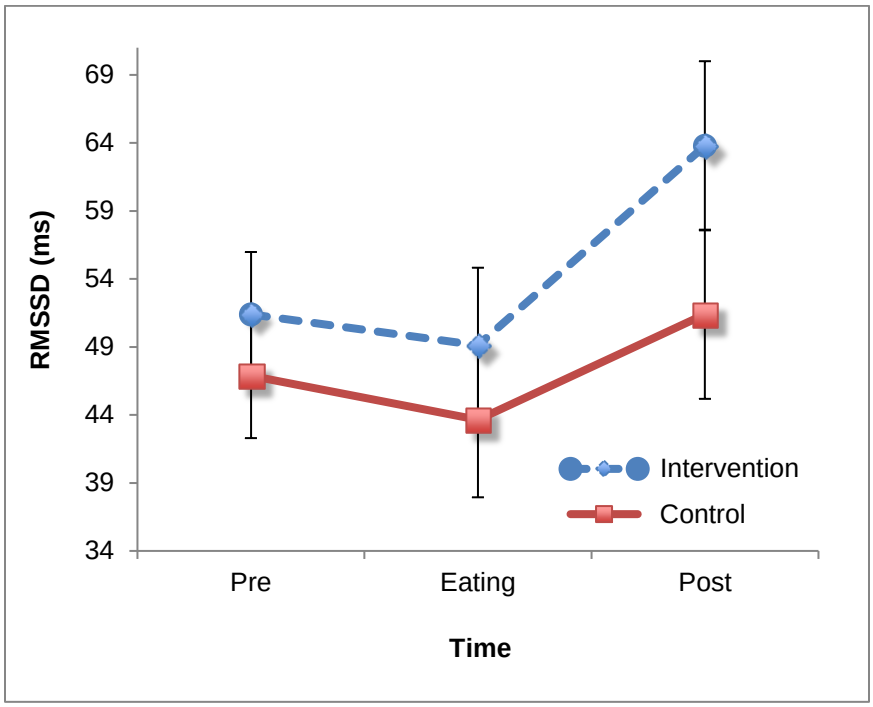


Figure 12. RMSSD response to fruit CS intake in Study 2. Raw values are presented here. RMSSD = root mean square of the difference of successive R-R intervals. Error bars represent standard errors.

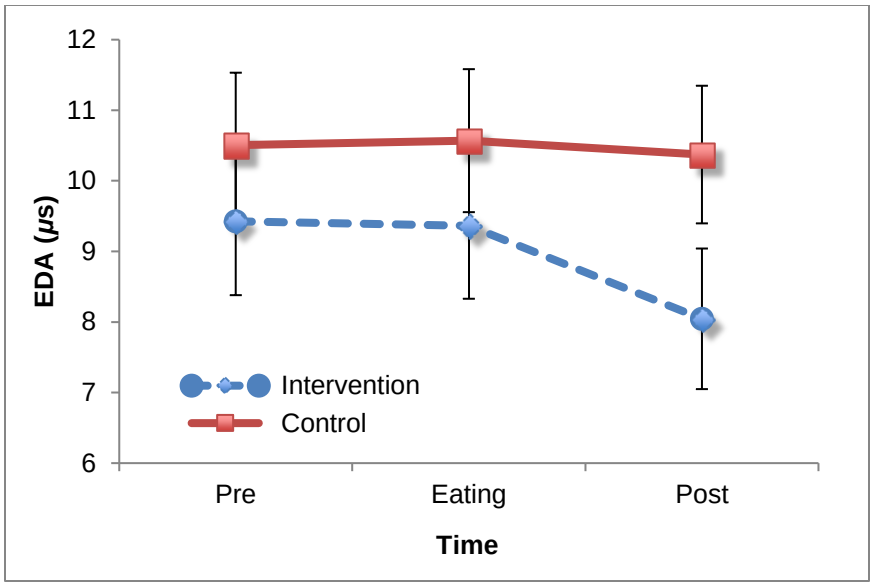


Figure 13. Electrodermal activity (EDA) response to fruits CS intake in Study 2. Raw values are presented here. Error bars represent standard errors.

HRV. A base model of HRV that included only a random intercept was used; when a random slope was also added to the model, the program did not generate an estimate for this variance component. This model with only a random intercept fit better than a model without this component (deviance of 442.2 vs. 550.2; deviance change $\chi^2(1.5)$ $p < .0001$), and also fit better than a model with only a random slope (deviance of 539.8; deviance change $\chi^2(1.5)$ $p < .0001$. In the chosen base model, HRV increased significantly over time, $t(195) = 72.34$, $p = .020$.

Changes in HRV across the 3 time points did not differ by condition, $\beta = 0.03$, $SE = 0.05$, $t(194) = 0.54$, $p = .590$, 95% CI [-0.08, 0.13].

EDA. The initial EDA model included both a random intercept and a random slope, as this model fit better than one without these variance components (deviance of 651.3 with vs. 932.6 without; deviance change $\chi^2(2)$ $p < .0001$). In this initial model, EDA did not change significantly over time, $t(98) = -1.68$, $p = .095$.

EDA trajectories across the 3 time points did not differ by condition, $\beta = -0.08$, $SE = 0.08$, $t(97) = -1.07$, $p = .287$, 95% CI [-0.24, 0.07].

Aim 2. Does the intervention promote healthier food intake outside of the lab?

Table 22 presents the results of ANOVA tests comparing the effect of condition on dietary outcomes from the 4-day food log period. As shown there, the two groups did not differ with regard to their intake of fruits, idiosyncratic fruit CS from prior trials, vegetables, unhealthy snacks, top-rated idiosyncratic unhealthy comfort foods specified at pre-intervention, total calories, total fat, saturated fat, trans fat, cholesterol, sodium, total sugars, or dietary fiber.[5]

[5] These results did not change when any demographic variables that were significantly associated with each outcome (e.g., gender, age, subjective social status) were included as covariates.

Table 22

Study 2 Dietary Intake by Condition

	Intervention Group (*n* = 48)		**Control Group (*n* = 49)**		
Outcome	***M* (*SD*)**	**Min-Max**	***M* (*SD*)**	**Min-Max**	***p***
Fruits (servings)	3.46 (3.19)	0-13	3.82 (3.68)	0-21	.611
CS fruit (servings)	0.14 (0.33)	0-1.25	0.18 (0.48)	0-2.25	.603
Vegetables (servings)	7.32 (7.05)	0.25-43	9.62 (8.42)	1-36.76	.149
Unhealthy snacks (count)	4.48 (2.95)	0-12	4.80 (3.16)	0-12	.612
Unhealthy comfort foods (count)	2.23 (3.04)	0-16	2.45 (3.14)	0-13	.727
Total calories (kcal)	1796.08 (588.72)	802-3826	1768.73 (537.22)	709-3321	.812
Total fat (g)	73.71 (29.50)	23-194	70.78 (21.965)	30-125	.579
Saturated fat (g)	23.17 (11.57)	4-66	21.76 (8.08)	8-41	.487
Trans fat (g)	0.44 (0.90)	0-4	0.31 (0.82)	0-5	.454
Cholesterol (mg)	322.35 (230.89)	12-1143	312.55 (229.64)	58-1239	.834
Sodium (mg)	2868.75 (1166.47)	904-7058	2622.84 (1167.20)	871-8192	.302
Total sugars (g)	66.08 (27.36)	31-144	65.24 (28.43)	14-149	.883
Total fiber (g)	17.00 (8.40)	5-41	18.53 (10.07)	4-55	.419

Note. Fruits, conditioned stimulus (CS) fruit, and vegetables represent total servings consumed across the 4 days. Unhealthy snacks and unhealthy comfort foods represent the total number of instances of these types of foods being consumed across the 4 days. The remaining outcomes represent average daily intake.

Aim 3. Does the intervention improve fruit pleasantness and intentions to buy?

Table 23 presents participants' average ratings for both their particular fruit CS as well as fruits overall on the dimensions of familiarity, pleasantness, and intentions to buy the fruit in the future from pre- to post-intervention by condition.

Table 23

Study 2 Fruit Ratings from Pre- to Post-Intervention by Condition

	Intervention Group		Control Group	
Outcome	**Time 1**	**Time 2**	**Time 1**	**Time 2**
Conditioned stimulus fruit				
Familiarity	80.36 (21.75)	93.24 (9.89)	84.50 (20.87)	94.30 (12.26)
Pleasantness	55.35 (9.40)	65.02 (22.24)	58.72 (11.94)	69.34 (22.47)
Likelihood of buying	50.88 (29.44)	60.50 (31.82)	54.86 (30.71)	71.32 (26.18)
Overall fruit				
Familiarity	84.83 (11.69)	84.06 (11.27)	88.78 (7.79)	86.07 (10.97)
Pleasantness	74.72 (14.65)	67.52 (14.41)	74.72 (11.87)	71.79 (13.33)
Likelihood of buying	62.69 (18.04)	62.51 (18.42)	69.22 (17.72)	64.83 (18.07)

Note. Fruit ratings are on a scale from 0-100, with higher scores indicating greater pleasantness or likelihood of buying the fruit in the future.

Conditioned stimulus fruit ratings. Across the entire sample, participants rated their fruit CS as more familiar at 1 week post-intervention (M = 93.77, SD = 11.09) than at baseline (M = 82.43, SD = 21.31), $F(1,98) = 30.74$, $p < .001$, $\eta_p^2 = .239$. This change over time was the same across conditions, $F(1,98) = 0.57$, $p = .45$.

Overall, participants rated their fruit CS as more pleasant at post-intervention (M = 67.18, SD = 22.35), compared to baseline (M = 57.05, SD = 10.82), $F(1,98) = 19.33$, $p < .001$, $\eta_p^2 =$ .165. However, this effect did not differ by condition, $F(1,98) = 0.05$, $p = .84$.

Across the entire sample, participants reported a greater likelihood to buy their assigned fruit CS at 1 week post-intervention (M = 65.91, SD = 29.49), compared to baseline (M = 52.87,

SD = 29.99), *F*(1,98) = 19.36, *p* < .001, $\eta_p^2 = .165$. However, this effect did not differ by condition, *F*(1,98) = 1.33, *p* = .25.

Overall fruit ratings. Across the entire sample, participants did not rate fruits overall as more familiar at post-intervention (*M* = 85.06, *SD* = 11.11) than at baseline (*M* = 86.80, *SD* = 10.08), *F*(1,98) = 3.70, *p* = .057. Condition did not interact with time to predict this overall fruit familiarity, *F*(1,98) = 1.16, *p* = .28.

Overall fruit pleasantness decreased over time from baseline (*M* = 71.91, *SD* = 13.56) to 1 week post-intervention (*M* = 69.65, *SD* = 13.98), *F*(1,98) = 7.52, *p* = .007, $\eta_p^2 = .071$. This effect was not moderated by condition, *F*(1,98) = 0.68, *p* = .41.

Overall likelihood to buy fruits did not change over time across the entire sample from baseline (*M* = 65.95, *SD* = 18.09) to 1 week post-intervention (*M* = 64.83, *SD* = 18.07), *F*(1,98) = 1.31, *p* = .26. Time did not interact with condition to predict overall likelihood to buy fruits, *F*(1,98) = 0.93, *p* = .34.

Aim 4. Does the intervention reduce perceived stress and depressive symptoms?

Perceived stress. Perceived stress decreased over time in the overall sample from baseline (*M* = 20.32, *SD* = 4.97) to Day 8 immediately post-intervention (*M* = 17.20, *SD* = 5.70), *F*(1,98) = 26.99, *p* = < .001, $\eta_p^2 = .216$. However, change in perceived stress over time did not differ between the intervention group (*M* = 21.38, *SD* = 5.22 to *M* = 17.92, *SD* = 6.01) and control group (*M* = 19.26, *SD* = 4.52 to *M* = 16.48, *SD* = 5.35), *F*(1,98) = 0.32, *p* = .57.

Depressive symptoms. Depressive symptoms did not change significantly over time in the overall sample from baseline (*M* = 16.66, *SD* = 9.53) to Day 8 immediately post-intervention (*M* = 16.22, *SD* = 9.42), *F*(1,98) = 0.19, *p* = .67. Furthermore, depressive symptoms over time

did not differ between the intervention group (*M* = 18.54, *SD* = 10.98 to *M* = 17.38, *SD* = 10.44) and control group (*M* = 14.78, *SD* = 7.46 to *M* = 15.06, *SD* = 8.22), *F*(1,98) = 0.50, *p* = .48.

Aim 5. Which factors moderate intervention effects?

Specifically, are effects of condition in Aims 1-4 are moderated by: (1) trait expectations that eating will improve mood, (2) scores on trait emotional eating, and (3) gender.

Repeated measures outcomes. Table 24 presents the results of tests of moderation for outcomes with repeated measures: positive mood, negative mood, HRV, EDA, perceived stress, depressive symptoms, and pleasantness and likelihood to buy for both overall fruit and fruit CS. Only one test suggested significant moderation, as described below.

Positive mood. The base model of positive mood included only a random intercept; when a random slope was also added, the program did not generate an estimate for the residual. This model with only a random intercept fit better than a model without this component (deviance of 1316.3 vs. 1450.2; deviance change $\chi^2(1.5)$ $p < .0001$), and also fit better than a model with only a random slope (deviance of 1448.0; deviance change $\chi^2(1.5)$ $p < .0001$.

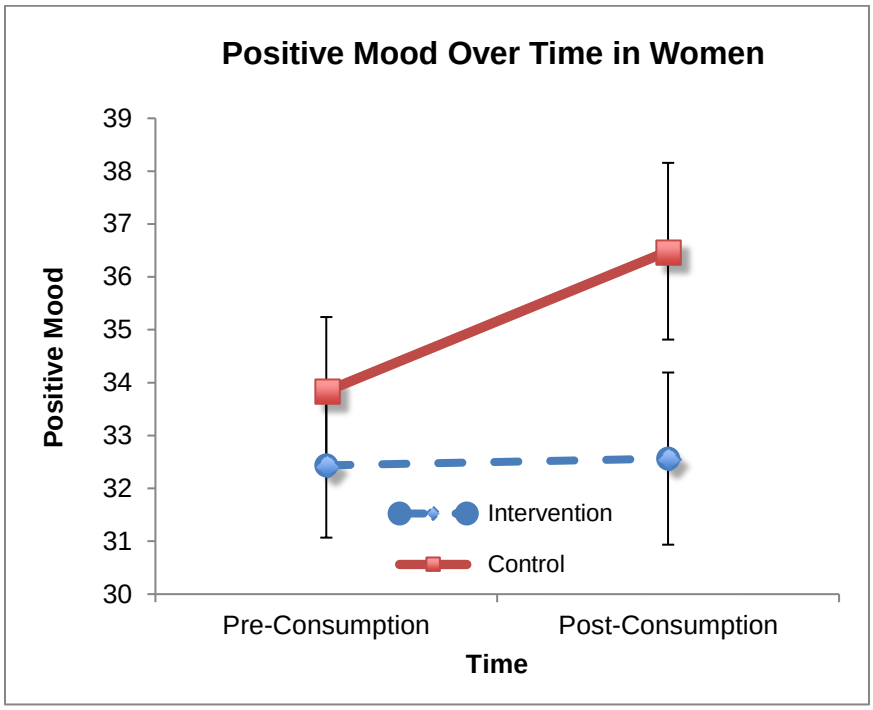
As shown in Table 24 and Figure 14, gender moderated the effect of the intervention on changes in positive mood from pre-post CS-fruit consumption, $\eta_p^2 = .076$. Among women, those in the intervention group showed no effect of fruit intake on positive mood, whereas fruit intake improved positive mood in the control group, interaction *F*(1, 74) = 5.45, *p* = .022, $\eta_p^2 = .069$. Among men, the effect of fruit intake on positive mood did not differ significantly by condition, interaction *F*(1, 22) = 3.71, *p* = .067, $\eta_p^2 = .144$. Post hoc analysis revealed that compared to men, women more strongly endorsed that they would use PMR as a stress reduction technique in the future (*M* = 3.42, *SD* = 1.38 vs. *M* = 4.18, *SD* = 1.52, respectively), *F*(1,98) = 4.85, p = .030. However, moderation by gender still remained after controlling for this acceptability variable.

Table 24

Study 2 Moderation Analyses for Repeated Measures Outcomes by Condition

Test	Estimate	*SE*	*df*	*t*	*p*	95% CI
Positive mood						
Trait emotional eating	-0.36	1.26	96	-0.28	.777	[-2.85, 2.14]
Comfort eating expectations	1.53	0.97	96	1.57	.120	[-0.40, 3.46]
Gender	6.18	2.20	96	2.81	**.006**	[1.81, 10.55]
Negative mood						
Trait emotional eating	0.11	0.85	96	0.13	.894	[-1.58, 1.81]
Comfort eating expectations	0.23	0.67	96	0.34	.732	[-1.10, 1.56]
Gender	-1.82	1.55	96	-1.18	.241	[-4.90, 1.25]
HRV						
Trait emotional eating	-0.07	0.07	192	-1.03	.304	[-0.21, 0.06]
Comfort eating expectations	0.01	0.05	192	0.16	.870	[-0.10, 0.11]
Gender	0.05	0.12	192	0.36	.717	[-0.29, 0.29]
EDA						
Trait emotional eating	-0.07	0.10	95	-0.66	.514	[-0.27, 0.14]
Comfort eating expectations	0.00	0.08	95	-0.05	.959	[-0.17, 0.16]
Gender	0.20	0.19	95	1.10	.274	[-0.16, 0.57]
Perceived stress						
Trait emotional eating	0.39	1.53	96	0.26	.797	[-2.63, 3.42]
Comfort eating expectations	0.43	1.23	96	0.35	.726	[-2.00, 2.87]
Gender	-2.13	2.83	96	-0.75	.454	[-7.75, 3.49]
Depressive symptoms						
Trait emotional eating	-2.80	2.54	96	-1.10	.272	[-7.84, 2.24]
Comfort eating expectations	0.87	2.07	96	0.42	.676	[-3.24, 4.98]
Gender	2.72	4.78	96	0.57	.571	[-6.76, 12.20]
Fruit CS pleasantness						
Trait emotional eating	-0.35	6.40	138	-0.06	.956	[-13.01, 12.30]
Comfort eating expectations	1.51	5.06	138	0.30	.766	[-8.50, 11.52]
Gender	4.17	11.70	138	0.36	.722	[-18.97, 27.31]
Fruits CS likelihood to buy						
Trait emotional eating	-3.83	7.67	96	-0.50	.619	[-19.05, 11.40]
Comfort eating expectations	-4.23	6.05	96	-0.70	.486	[-16.23, 7.78]
Gender	-1.06	14.01	96	-0.08	.940	[-28.87, 26.74]
Overall fruit pleasantness						
Trait emotional eating	3.18	2.08	96	1.53	.129	[-0.95, 7.30]
Comfort eating expectations	0.67	1.67	96	0.40	.688	[-2.65, 4.00]
Gender	-0.13	3.86	96	-0.03	.973	[-7.79, 7.52]
Overall fruit likelihood to buy						
Trait emotional eating	3.33	2.53	96	1.32	.191	[-1.69, 8.36]
Comfort eating expectations	0.37	2.01	96	0.18	.856	[-3.63, 4.37]
Gender	-4.25	4.65	96	-0.91	.363	[-13.47, 4.97]

Note. Each test represents the 3-way interaction between condition, time, and the moderator of interest. CI = confidence interval.



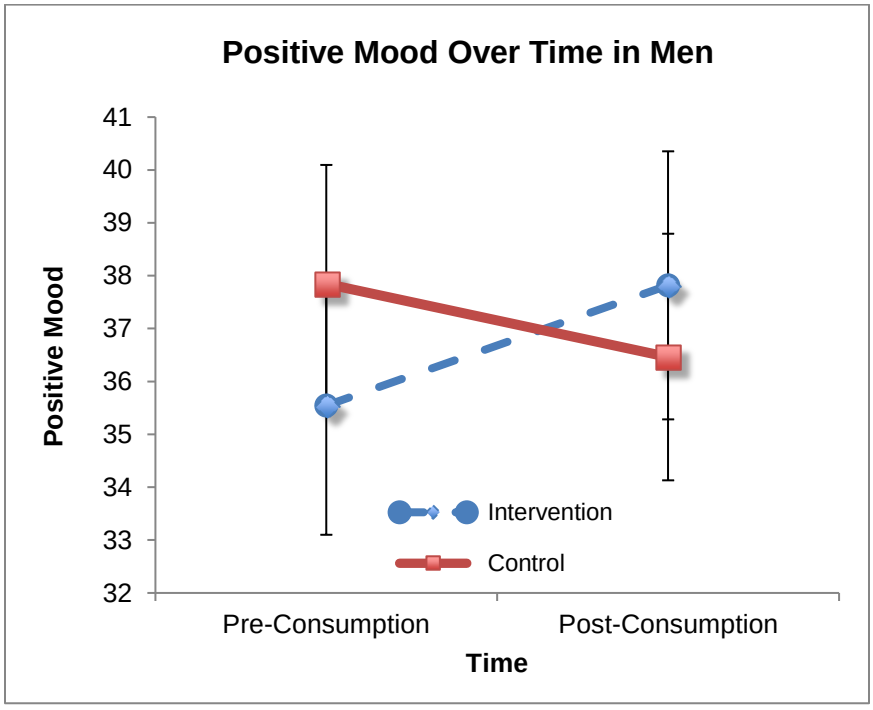


Figure 14. Positive mood response to fruit CS intake in Study 2 by gender and condition. Values represent scores on the positive mood subscale of the Positive and Negative Affect Schedule. Error bars represent standard errors.

Negative mood. A base model of negative mood that included only a random intercept was used. When a random slope was also added to the model—either by itself or with a random intercept—the program did not generate an estimate for this variance component. The chosen base model with only a random intercept fit better than a model without this component (deviance of 1129.5 vs. 1230.4; deviance change $\chi^2(1.5)$ $p < .0001$).

As shown in Table 24, trait emotional eating, comfort eating expectations, and gender each did not interact with time and condition to predict negative mood.

HRV and EDA. The same base models for HRV and EDA in Aim 1 were used when testing for moderation. As shown in Table 24, trait emotional eating, comfort eating expectations, and gender each did not interact with time and condition to predict HRV or EDA.

Perceived stress. The base model of perceived stress included only a random intercept; when a random slope was also added, the program did not generate an estimate for the residual. This model with only a random intercept fit better than a model without this component (deviance of 1220.3 vs. 1240.5 deviance change $\chi^2(1.5)$ $p < .0001$), and also fit better than a model with only a random slope (deviance of 1233.4; deviance change $\chi^2(1.5)$ $p < .001$.

As shown in Table 24, trait emotional eating, comfort eating expectations, and gender each did not interact with time and condition to predict perceived stress.

Depressive symptoms. The base model of depressive symptoms included only a random intercept; when a random slope was also added, the program did not generate an estimate for the residual. This model with only a random intercept fit better than a model without this component (deviance of 1441.4 vs. 1461.5; deviance change $\chi^2(1.5)$ $p < .0001$). A model with only a random slope was not ideal, as it did not generate an estimate for this variance component.

As shown in Table 24, trait emotional eating, comfort eating expectations, and gender each did not interact with time and condition to predict depressive symptoms.

Fruit CS pleasantness. The base model of fruit CS pleasantness that included only a random slope; when a random intercept was also added, the program did not generate an estimate for the residual. This model with only a random slope fit better than one without this component (deviance of 1657.7 vs. 1705.8 deviance change $\chi^2(1.5)$ $p < .0001$), and also fit better than a model with only a random intercept (deviance of 1703.6; deviance change $\chi^2(1.5)$ $p < .001$.

As shown in Table 24, trait emotional eating, comfort eating expectations, and gender each did not interact with time and condition to predict fruit CS pleasantness.

***Fruit CS likelihood to buy*.** The base model of fruit CS likelihood to buy included only a random intercept. When a random slope was also added to the model—either by itself or with a random intercept—the program did not generate an estimate for one of the variance components. The chosen base model with only a random intercept fit better than a model without this component (deviance of 1885.8 vs. 1914.6; deviance change $\chi^2(1.5)$ $p < .0001$).

As shown in Table 24, trait emotional eating, comfort eating expectations, and gender each did not interact with time and condition to predict fruit CS likelihood to buy.

***Overall fruit pleasantness*.** The base model of overall fruit pleasantness included only a random intercept; when a random slope was also added, the program did not generate an estimate for the residual. This random intercept only model fit better than one without this component (deviance of 1498.1 vs. 1609.7 deviance change $\chi^2(1.5)$ $p < .0001$), and also fit better than a model with only a random slope (deviance of 1609.6; deviance change $\chi^2(1.5)$ $p < .001$.

As shown in Table 24, trait emotional eating, comfort eating expectations, and gender each did not interact with time and condition to predict overall fruit pleasantness.

Overall fruit likelihood to buy. The base model of overall fruit likelihood to buy included only a random intercept. When a random slope was also added to the model—either by itself or with a random intercept—the program did not generate an estimate for one of the variance components. The random intercept only model fit better than one without this component (deviance of 1589.3 vs. 1717.4; deviance change $\chi^2(1.5)$ $p < .0001$).

As shown in Table 24, trait emotional eating, comfort eating expectations, and gender each did not interact with time and condition to predict overall fruit likelihood to buy.

Dietary intake. Table 25 presents the results of tests of moderation for dietary outcomes: total servings of fruits, CS fruit, and vegetables; total number of instances of eating unhealthy snacks and unhealthy comfort foods; and average daily intake of calories, total fat, saturated fat, trans fat, cholesterol, sodium, total sugars, and total fiber.

Table 25

Study 2 Moderation Analyses for Dietary Intake by Condition

	Trait Emotional Eating		**Comfort Eating Expectations**		**Gender**	
Outcome	***t***	***p***	***t***	***p***	***t***	***p***
Fruits (servings)	0.04	.968	1.82	.072	0.17	.867
CS fruit (servings)	1.76	0.08	-0.03	.976	-0.63	.530
Vegetables (servings)	-0.93	.353	0.86	.393	0.09	.930
Unhealthy snacks (count)	1.20	.233	-0.64	.524	-0.06	.949
Unhealthy comfort foods	-1.64	.105	-0.93	.355	0.47	.641
Total calories (kcal)	-1.40	.165	-2.32	**.023**	0.76	.447
Total fat (g)	-0.57	.569	-1.81	.074	0.52	.601
Saturated fat (g)	-0.12	.906	-2.16	**.034**	0.30	.762
Trans fat (g)	1.66	.101	0.92	.360	-1.10	.274
Cholesterol (mg)	-0.67	.504	0.07	.942	0.43	.665
Sodium (mg)	-1.24	.217	-1.70	.092	0.48	.631
Total sugars (g)	-0.81	.420	-0.67	.504	0.50	.619
Total fiber (g)	-0.59	.557	0.69	.492	0.00	.999

Note. Fruits, conditioned stimulus (CS) fruit, and vegetables represent total servings consumed. Unhealthy snacks and unhealthy comfort foods represent the total number of instances of these types of foods being consumed. The remaining outcomes represent average daily intake.

Moderation by comfort eating expectations. As shown in Table 25, the effect of condition on average daily intake of calories and saturated fat both depended upon comfort eating expectations. To probe these interactions, the effect of condition was examined separately among those low (n = 50) and high (n = 47) on comfort eating expectations, determined by a median split.

Calorie intake. As shown in Figure 15, for participants low on comfort eating expectations, those in the intervention group showed significantly greater average daily calorie intake (M = 1997.95) than those in the control group (M = 1663.32), t = 2.15, p = .034, 95% CI [25.53, 643.74]. However, for participants high on comfort eating expectations, condition did not affect average daily calorie intake, t = -1.77, p = .080.

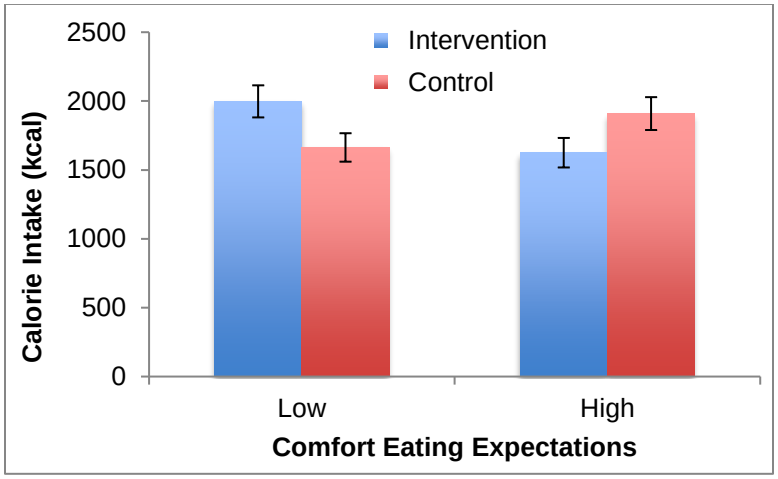


Figure 15. Average daily calorie intake in Study 2 by condition and comfort eating expectations. Comfort eating expectations categories represent one standard deviation below and one standard deviation above the mean for this variable.

Saturated fat intake. As shown in Figure 16, for participants low on comfort eating expectations, those in the intervention group consumed significantly more daily saturated fat (M = 26.41) than those in the control group (M = 20.41), t = 2.13, p = .035, 95% CI [0.42, 11.47]. However, for participants high on comfort eating expectations, average daily saturated fat intake did not differ by condition, t = -1.06, p = .290.

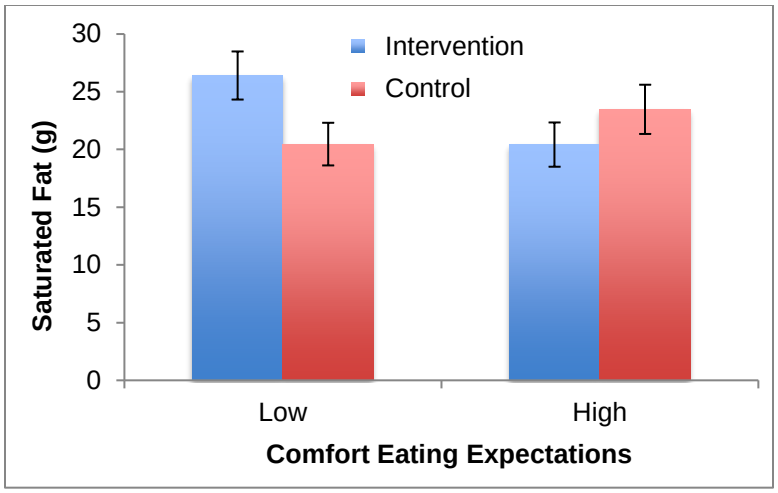


Figure 16. Average daily saturated fat intake in Study 2 by condition and comfort eating expectations. Comfort eating expectations categories represent one standard deviation below and one standard deviation above the mean for this variable.

Post hoc tests. Post hoc analysis revealed that those low versus high on comfort eating expectations (determined via median split) more strongly endorsed that they had engaged in the PMR the appropriate number of times (M = 5.91, SD = 0.30 vs. M = 5.57, SD = 1.02, respectively), $F(1,98) = 5.15$, $p = .025$. After including this variable as a covariate in the above models of calories and saturated fat, the observed moderation effects still persisted.

All other moderation tests. Trait emotional eating, comfort eating expectations, and gender each did not interact with condition to predict any other dietary outcomes.

Summary of Findings

Aim 1: Acute Psychophysiological Impacts

I hypothesized that after all trials were completed, that CS fruit intake in the lab would have a greater stress-reducing impact on participants in the intervention group compared to controls. Supporting this hypothesis, CS fruit intake elicited a larger reduction in negative mood among those in the intervention group. However, there were no group differences in effects on other psychophysiological markers, including positive mood, heart rate variability, and

electrodermal activation. Therefore, these results indicate that individuals with moderate to high stress levels can be conditioned to experience fruit intake as somewhat helpful for repairing mood; however, the conditioned response may be limited in scope and not apply to physiological stress markers.

Aim 2: Healthy and Unhealthy Food Intake

At post-intervention, I expected that those in the intervention group would show more favorable dietary intake outside of the lab in terms of both greater intake of healthy food (i.e., fruits, fruit CS from trials, vegetables, and dietary fiber) and lower intake of unhealthy food (i.e., unhealthy snacks, top-rated idiosyncratic unhealthy comfort foods specified at pre-intervention, total calories, total fat, saturated fat, trans fat, cholesterol, sodium, and total sugars). Results did not support this hypothesis, however; there were no group differences in these dietary outcomes across the 4 days of home food monitoring.

Aim 3: Fruit Perceptions

In the overall sample, participants reported being about 13% more likely to buy their idiosyncratic fruit CS at post-intervention compared to baseline, and also rated their fruit CS as significantly more pleasant at post-intervention. However, contrary to my hypotheses, these improvements were not of a greater magnitude in the intervention group compared to controls.

With regard to ratings of fruits as a whole, the overall sample did not report being any more or less likely to purchase fruits from pre- to post-intervention. Interestingly, the sample rated fruits overall as being significantly less pleasant at post-intervention. Contrary to my hypotheses, condition did not moderate either of these effects. Therefore, it does not seem that the intervention had any effects of stimulus generalization regarding overall fruit perceptions.

Aim 4: Perceived Stress and Depressive Symptoms

I expected that those in the intervention group would show greater improvement in perceived stress and depressive symptoms from pre- to post-intervention. Results showed that perceived stress decreased over time in the overall sample, but depressive symptoms did not. Neither of these effects differed between the two conditions.

Aim 5: Moderation

I hypothesized that beneficial effects of the intervention on the aforementioned outcomes would be greater in women, in those who express greater comfort eating expectations, and those with higher levels of trait emotional eating. Three results suggested moderation, but none were consistent with my hypotheses.

First, among female participants, only those in the control group showed improvements in positive mood after fruit CS intake in the lab; men overall and women in the intervention group all did not show any fruit-induced changes in positive mood.

With regard to dietary outcomes, among participants with a lower level of comfort eating expectations, those in the intervention group showed higher intake of both calories and saturated fat compared to controls. However, among those with a higher level of comfort eating expectations, there were no differences in these outcomes by condition.

Discussion

Study 1

Main findings. Study 1 aimed to fill several key gaps in the comfort eating literature as the first human study to assess the effects of comfort eating type (healthy or unhealthy) and timing (before or after a stressful event) on acute psychophysiological stress reactivity and recovery. These relationships were examined in a sample of healthy young undergraduate

women in the context of a reliable laboratory stress paradigm. Results revealed that compared to a no-food control, healthy or unhealthy comfort eating before the stressful event did not dampen psychophysiological stress reactivity, nor did either type of comfort eating after the stressor hasten psychophysiological stress recovery. Furthermore, psychophysiological outcomes were no different when comparing the two types of comfort eating to one another, as well as when comparing the two comfort eating timings to one another.

Timing. The present results differ from previous rodent findings (Foster et al., 2009; Ulrich-Lai et al., 2007) in that comfort eating taking place *before* the stressor did not did not dampen stress reactivity. These findings contrast with prior evidence from Wagner et al. (2014) that consuming chocolate before a negative event dampens negative mood reactivity. In addition, the lack of buffering effects of comfort eating *after* the stressor diverges with prior findings that palatable chocolate consumption improves mood after a negative event (Macht & Mueller, 2007), although others have found that post-event comfort eating does not confer psychological benefits (Wagner et al., 2014). However, these latter studies examined comfort eating in the context of laboratory-induced sadness (Macht & Mueller, 2007; Wagner et al., 2014), whereas the present study assessed responses to an acute laboratory stressor.

Physiological responses. The current study's physiological findings diverge from those of prior studies in rodents that have evidenced dampening effects on neuroendocrine stress responses (Dallman et al., 2003; Foster et al., 2009; Pecoraro et al., 2004; Ulrich-Lai et al., 2007). Therefore, perhaps comforting effects on neuroendocrine stress physiology are species-specific. Indeed, an experiment in 10 adult rhesus monkeys found that the provision of high- versus low-calorie diet for 3 weeks did not reduce cortisol response to acute social separation, but it did decrease anxiety-like behaviors (Arce, Michopoulos, Shephard, Ha, & Wilson, 2010).

Another possibility is that human physiological stress-reducing effects of comfort eating are primarily observed in the immune system. One study in healthy men found that intake of flavanol-rich dark chocolate versus flavanol-free placebo chocolate 2 hours before the Trier Social Stress Test led to significantly blunted intracellular pro-inflammatory stress responses for the outcomes of NF-κB-BA, IL-1β mRNA, and IL-6 mRNA (Kuebler et al., 2016).

Methodological considerations. There may be methodological considerations that prevented a stress-buffering signal from occurring or being detected in the present study. With regard to autonomic recovery from stress, it is noteworthy that during the time from the TSST speech task through immediately post-TSST, both autonomic markers had had already recovered substantially, and did not significantly change any further over the remainder of the assessment period. In other words, recovery of the autonomic nervous system may have occurred so quickly that by the time the "after" eating manipulation took place, it was too late to have an effect on autonomic recovery. It is also possible that participants did not feel as comfortable consuming their top-rated comfort food in the laboratory setting as they would in the privacy of their own home, potentially inhibiting the occurrence of comforting effects.

Moderation. There was only one instance in which the effects of healthy and unhealthy comfort eating did differ. Among those with low trait emotional eating, those who ate healthy food before the stressor did not show significant cortisol reactivity, whereas those who ate unhealthy food did show significant cortisol reactivity. It is possible that perhaps these women low on trait emotional eating may also have been more of healthy eaters in other dimensions like eating more fruits and vegetables. Accordingly, perhaps consuming a healthy fruit or vegetable in the lab reduced their stress levels because they acted in a way that re-affirmed their self-concept as a healthy eater. However, data from Study 2 did not show any correlation between

trait emotional eating scores and total servings of fruits or vegetables, which does not support this explanation. Regardless, I recommend the observed moderating effect be interpreted with caution, as this finding was the only one out of many tests to evidence any type of stress-dampening, and a similar pattern of results was not found for other markers of stress reactivity. Thus, without replication in additional research, it should not be given much empirical weight.

The fact that chronic stress levels did not play a moderating role in Study 1 lies in contrast with results from prior studies in the literature. For example, (Tomiyama et al., 2011) found that those with high versus low chronic stress (assessed by the Perceived Stress Scale; Cohen et al., 1983) also showed higher levels of emotional eating and a blunted cortisol response to acute stress in the laboratory. One potential explanation for this inconsistency may be BMI. Tomiyama and colleagues had also found that these high stress women had higher BMI and greater sagittal diameter than low stress women, consistent with the *chronic stress response network* model posited by Dallman et al. (2003) wherein abdominal fat may be suppressing HPA axis responses via negative feedback. Tests of physiological stress-buffering in the present studies included BMI as a covariate, which could have conceptually had the effect of controlling for an important mechanism; however, the outcomes of these tests remained the same when BMI was not included as a covariate, dispelling this statistical concern. It is also noteworthy that the participants in Studies 1 and 2 each fell into the normal weight category on average (M = 22.45 and M = 23.81, respectively), whereas the participants in the high and low stress groups in Tomiyama et al. (2011) fell into the overweight (M = 25.97) and normal weight (M = 23.89) categories, respectively. Therefore, the present studies' participants may have been more similar to the low-stress women in the prior study in terms of BMI, perhaps explaining the discrepancies in cortisol dampening between these study populations.

Given that no main effects of comfort eating were observed in this study, it did not make conceptual sense to test whether feelings of guilt or comfort food sugar content may be serving as mediating pathways. With regard to macronutrient content, Wouters et al. (2018) found that carbohydrate intake enhanced the dampening effect of naturally-occurring snacking on the relationship between daily hassles and negative affect reactivity. However, in another study greater self-reported comfort eating predicted decreased expected odds of all-cause mortality after accounting for other health and demographic factors, and this effect was not mediated by high-fat/sugar intake (Cummings, Mason, Puterman, & Tomiyama, 2017). Further research should continue to examine and elucidate the numerous potential mechanisms driving beneficial comfort eating effects (Tomiyama et al., 2015).

Study 2

Main findings. Study 2 tested whether men and women who exhibit a moderate to high level of baseline stress can learn to experience healthy food intake as comforting. Pavlovian conditioning methodology was used to encourage the intervention group to forge an association between fruit intake and stress relief, whereas the control group engaged in all of the same study activities but did not temporally pair together fruit intake and stress relief. At post-intervention, results showed that as expected, fruit intake elicited a greater reduction in negative mood among the intervention group than the control group. However, the effects of the fruit intake on positive mood and autonomic stress markers did not differ between the two groups. In addition, the intervention group did not show greater intake of healthy foods and lower intake of unhealthy foods at the end of the study. Furthermore, compared to the control group, the intervention group did not show greater improvements from pre- to post-intervention in perceived stress, depressive symptoms, or ratings of fruit pleasantness and intentions to buy fruit in the future.

Comforting effects. The present study is the first known experiment aiming to condition comforting psychophysiological effects of fruit intake. Results were mixed in this regard, showing benefits of fruit CS intake for negative mood, but not for physiological markers. Therefore, perhaps salubrious psychological impacts of healthy food intake can be learned, but not acute physiological stress-dampening effects. However, as noted again later in *methodological considerations*, it is also possible that a greater level of baseline stress may have been necessary for fruit CS intake to have had "room" to have a physiological stress-dampening effect. Regardless, the observed acute impact of fruit CS intake on negative mood provides preliminary support for Pavlovan conditioning as a method for stressed individuals to develop a salubrious psychological response to fruit consumption. Further research should assess whether this conditional response is only present for a short number of minutes, or whether it might persist for a longer period of time.

Dietary intake. The lack of differences in fruit intake between the two conditions at post-intervention are in contrast with another conditioning study conducted by Walsh and Kiviniemi (2014). In that study, participants who repeatedly viewed images of fruits paired with positive versus neutral affective stimuli were twice as likely to choose a fruit instead of a granola bar. However, these researchers only looked at one individual food choice with limited options (i.e., an assortment of fruits and granola bars), and they also assessed food choice immediately after the conditioning took place (on the same day in the lab). In contrast, the present study assessed everyday food intake for 4 days beginning at 4 days after the last trial. Therefore, the present study provided a more rigorous test of conditioning effects by utilizing a longer training-test interval and allowing participants unlimited options with regard to their food intake.

Perceived stress and depressive symptoms. The overall improvement in chronic perceived stress levels from pre- to 1 week post-intervention across the entire sample is consistent with other studies showing a positive impact of PMR on perceived stress (Carlson & Hoyle, 1993). However, depressive symptoms did not also decrease over time, which is divergent with prior research findings that PMR (Manzoni et al., 2009) and fruit intake (Smith & Rogers, 2014) reduce depressive symptoms. Nevertheless, the two conditions did not show differential changes in these outcomes over time. This may have been related to the timing of the second assessment of these outcomes. This second assessment occurred on Day 15, and asked participants to look back on their thoughts and feelings within the past week. Thus, in the time period being asked about, the intervention trials had all already taken place, and participants were either on off days from the study or completing their 4 days of food diaries. Day 15 was chosen for this follow-up as a more rigorous test, as this provided a weeklong washout period since the last dose of the intervention. However, assessing perceived stress and depressive symptoms on Day 8—the day immediately after the final conditioning trial—may have been the most potent time for capturing any impacts of the intervention on these outcomes.

Fruit ratings. With regard to the fruit ratings results, these findings are in contrast with other studies in which participants showed increased desire to eat initially disliked or neutral foods after viewing photos of others making pleasant faces with the foods (Barthomeuf et al., 2012) or after the foods were repeatedly paired with positive social attention from others (Birch et al., 1980). One potential explanation for these divergent findings may be the age of the participants, as these prior findings were observed in children aged 5-8 years (Barthomeuf et al., 2012) and 3-5 years (Birch et al., 1980), whereas the present study's participants were college-aged young adults aged ~20-21 years on average. Indeed, Barthomeuf et al. (2012) also

conducted trials in adults and found that changes in food liking consistently occurred to a greater extent among the children than the adults. Participant age is an important consideration because individuals become more familiar with various foods with increasing age, and less novel foods can require a greater number of conditioning trials to form a new conditional response (Hall & Pearce, 1979; Lubow & Gewirtz, 1995).

Methodological considerations. The present study began by only providing participants with a fruit CS that they rated as rather novel (i.e., < 40/100 on familiarity) at baseline. However, perhaps given the age of the participants and the setting of the study (Southern California, where an abundance of diverse fruits are available year-round), there were very few fruits (if any) that fit this criterion for each individual at pre-screening, and most individuals reported being highly familiar with each fruit at baseline. Therefore, the original novelty requirement was lifted, as it was not realistic for study recruitment. However, participants were still assigned a fruit CS that was as novel as possible while also meeting the neutrality requirement (i.e., 40-75/100 on pleasantness). Although average fruit CS familiarity was rather high in the sample at baseline, it did significantly increase from pre- to post-intervention, suggesting that there was still "room" for familiarity to improve with greater exposure in the trials. Therefore, although greater baseline CS novelty may have been preferred, perhaps this factor did not impede the formation of the desired CR in the present study.

Measures were also taken at the beginning of the study to increase the likelihood that only individuals who enjoyed PMR would be enrolled, and that participants would be assigned a fruit CS that was relatively neutral to them at baseline. However, on the final day of the study, about 32% of participants provided negative feedback about the PMR, the selected CS fruit, or both—namely, that they either did not like these components, that they found them to be

repetitive, or that they believed participants may have appreciated having other fruit or recording options. Therefore, it is possible that perhaps the intervention group did not show consistent stress-buffering effects because during their paired trials, the unconditional stimulus (PMR) may have not elicited the expected unconditional response (stress relief), and the conditional stimulus (fruit) may have had too strong of a negative pre-existing (and perhaps worsening) association in these participants' experiences. This notion is not supported by post hoc analyses, however; repeating all analyses with these participants excluded did not change the pattern of results. Nevertheless, in light of the feedback these participants provided, future studies attempting to employ Pavlovian conditioning to promote stress-reducing effects of healthy food should consider altering the conditioning methods of the current study by: 1) selecting a CS that is rated on the higher end of the neutral spectrum (e.g., 60-75 pleasantness out of 100 rather than the present study's 40-75); 2) asking participants to perform the trials every other day rather than on 7 consecutive days; 3) somewhat reducing the number of conditioning trials; and 4) varying the content of the US to a greater extent.

Future studies attempting to condition comforting effects of healthy foods should also consider utilizing an activity to induce the US (stress relief) that is characteristically different than PMR. There is some evidence that PMR may reduce feelings of hunger (Pawlow, O'Neil, & Malcolm, 2003) and dietary intake (Vander Wal, Maraldo, Vercellone, & Gagne, 2015) among clinical samples with night-eating syndrome, and another study found that 3 months after a relaxation intervention (i.e., nine PMR sessions administered across 3 weeks), obese emotional eaters reported significantly less emotion-induced eating than controls (Manzoni et al., 2009). Therefore, pairing PMR with CS fruit intake in the present study may have had the unintended effect of *suppressing* rather than promoting appetite for fruits. However, this potential concern

may be mitigated by the fact that all participants were asked to fast for the 3 hours preceding fruit intake, which likely ensured that some level of hunger was present at the start of the trials to increase the salience of the fruit. Indeed, participants reported a moderate level of hunger at the start of the final lab visit after being asked to fast during the 3 hours leading up to the visit.

Finally, the present study recruited participants who exhibited a moderate to high level of chronic perceived stress for their age and gender, with the rationale that these participants would then have some baseline level of stress to then be reduced by healthy comfort eating throughout the course of the study. Future studies might also consider inducing acute stress both before each conditioning trial and at the time of post-intervention assessment of fruit CS effects in order to strengthen formation of conditional responding and to confirm that there is indeed "room" for the fruit CS to reduce stress. I do note, however, that participants in the present study were encouraged to complete their trials outside of the lab at times when they were feeling particularly stressed on each given day.

Moderation. Three findings suggested moderation in unexpected ways. First, among female participants, only those in the control group showed improvements in positive mood after fruit CS intake in the lab. Regarding food intake at post-intervention, among those with a lower comfort eating expectations, control participants showed lower intake of both calories and saturated fat compared to those in the intervention group. A consistent theme across these results is that the control group yielded more favorable outcomes than the intervention group.

Perhaps this pattern may be related to acceptability data for the PMR task. Across the overall sample, those in the control versus intervention group reported that the PMR made them feel significantly more relaxed and endorsed stronger sentiments that they would use the PMR as a stress reduction technique in the future. PMR acceptability data also somewhat differed by the

present moderators of interest. Compared to men, women more strongly endorsed that they would use the PMR as a stress reduction technique in the future. Furthermore, those low versus high on comfort eating expectations more strongly endorsed that they had engaged in the PMR the appropriate number of times. However, the observed moderating effects persisted in post hoc tests after including these respective PMR acceptability variables as covariates.

A second potential reason why the control group may have fared better for these three results may be that a significantly greater number of intervention than control group participants reported on the last day of the study via free response that they did not particularly enjoy fasting prior to their fruit intake. Thus, perhaps this 18% of intervention participants began to develop negative—rather than positive—associations with fruit CS intake. However, this would still not explain why the observed differences by condition only occurred in women and those with low comfort eating expectations. In sum, I recommend that these moderating effects be interpreted with caution barring additional evidence from further research.

General Discussion

The present studies fill several key gaps in the comfort eating literature, as they represent the first known research in humans to: 1) experimentally test the capacity of healthy and unhealthy comfort eating to dampen human psychological, autonomic, and neuroendocrine responses to stress, compared to a non-food control; 2) examine potential moderation of these stress-reducing effects by individual difference variables; and 3) utilize Pavlovian conditioning methodology to repeatedly pair stress relief with healthy eating and subsequently test for impact on the comforting capacities of fruit, as well as perceptions and intake of healthy food.

Findings suggest that unhealthy comfort eating of processed, high-calorie/fat/sugar foods does not function to dampen markers of psychophysiological stress compared to eating no food

in healthy young adults. Healthy comfort eating of fruits or vegetables also does not appear to initially reduce human psychophysiological stress compared to eating no food, but fruit intake may repair negative mood after 5-7 instances of pairing fruit intake with relaxation.

In light of the present studies' overall absence of observed stress-reducing effects in the laboratory, perhaps human comfort eating primarily buffers the psychological impact of naturally-occurring stressors in everyday life (Finch & Tomiyama, 2015) rather than administered experimental stressors. For example, a recent observational study using experience sampling found that snacking outside of the lab dampened the effect of daily hassles on negative affect reactivity (Wouters, Jacobs, Duif, Lechner, & Thewissen, 2018).

Or, it may be that comfort foods are most comforting to humans not in the context of stress but rather in the face of other negative emotional states. For example, compared to eating nothing at all, comfort eating after social rejection may reduce distress (Scherschel, 2016) and consuming palatable chocolate after viewing sad film clips may improve mood (Macht & Mueller, 2007). Future studies can continue advancing the science of human comfort eating by testing for beneficial impacts on additional emotion-related outcomes such as anger, loneliness, and symptoms of depression and anxiety (Tomiyama et al., 2015).

Nevertheless, the present findings leave the door open for individuals to shift their comfort eating behavior away from unhealthy foods and toward healthy foods. Although there is some evidence that comfort food may be a protective factor buffering the impact of adverse life events on perceived stress (Finch & Tomiyama, 2015), the content of the food in that study was unknown. With regard to physical health outcomes, given that benefits of comfort eating for all-cause mortality do not appear to be mediated by high-fat/sugar foods in particular (Cummings et al., 2017), perhaps it is the act of comfort eating in general—rather than unhealthy food content

in particular—that can bring protective benefits for health. Indeed, unhealthy foods did not seem to dampen stress responses in the present research, suggesting that individuals may not be missing out on any benefits of this behavior by replacing it with healthy food intake instead. Furthermore, although consumption of flavanol-rich dark chocolate may dampen acute pro-inflammatory stress responses (Kuebler et al., 2016), flavanols are also present in some healthy foods like berries, apples, grapes, citrus fruit, and legumes. Importantly, by transforming their comfort eating toward healthy comfort eating, individuals will inherently receive the benefit of improved dietary nutrition and in turn, decrease their risk of morbidity and mortality over time.

Appendices

Appendix A. Study 1 Pre-Questionnaires

Demographic Questionnaire

Please complete the following personal information:

1. Sex: M F
2. Age _____
3. What is your racial/ethnic heritage?
    a. White/Anglo or European American
    b. Black/African American, Carribean
    c. Asian, Asian American, Pacific Islander
    d. Hispanic/Latino(a)
    e. Native American
    f. Arabic/Middle Eastern
    g. Bi-racial
        i. _____
        ii. _____
    h. Other
        i. _____
4. What is your weight in pounds? _____
5. What is your height in feet and inches? _____
6. Please rate yourself on the following scale:

1	2	3	4	5	6	7
Very thin			Average			Very heavy

7. Do you have a history of an eating disorder? Y N
8. Do you have a history of substance abuse? Y N
9. Are you on a strict diet? Y N
10. Do you have any food/beverage allergies? Y N
    a. What are your food/beverage allergies? _____
11. Is English your primary language? Y N

a. If not, are you fluent in English? Y N

12. Do you take any medications that are known to affect hormones (e.g., glucocorticoids, oral contraceptives)? Y N
    a. If yes, which medication(s)? _____

13. Do you have a metabolic or endocrine disease such as diabetes? Y N

14. Do you have any current major illness or injury? Y N

15. Do you have any current diagnosed psychiatric condition (e.g., bipolar disorder)? Y N

16. Are you post-menopausal? Y N

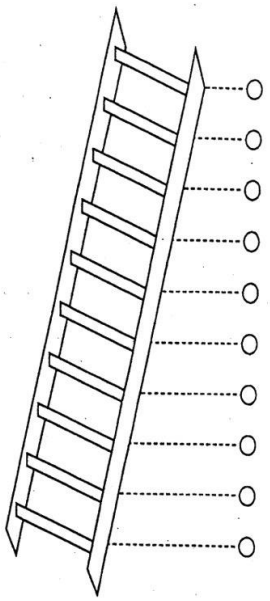
17. Please indicate the number choice below that you feel was most representative of your family's annual household income when you were growing up:
    a. less than $10,000
    b. $ 10,000-$19,999
    c. $ 20,000-$29,999
    d. $30,000-$39,999
    e. $40,000-$49,999
    f. $50,000-$59,999
    g. $60,000-$69,999
    h. $70,000-$79,999
    i. $80,000-$89,999
    j. $90,000-$99,999
    k. $100,000-$124,999
    l. $125,000-$149,999
    m. greater than $150,000

18.

1a. Imagine that this ladder pictures how American society is set up.

- At the top of the ladder are the people who are the best off--they have the most money, the highest amount of schooling, and the jobs that bring the most respect.
- At the bottom are people who are the worst off--they have the least money, little or no education, no job or jobs that no one wants or respects.

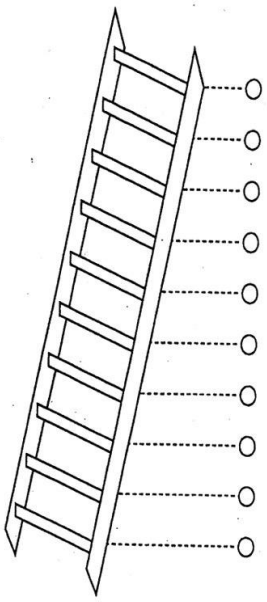
Now think about your family. Please tell us where you think your family would be on this ladder. **Fill in the circle that best represents where your family would be on this ladder.**



1b. Now assume that the ladder is a way of picturing your school.

- At the top of the ladder are the people in your school with the most respect, the highest grades, and the highest standing.
- At the bottom are the people who no one respects, no one wants to hang around with, and have the worst grades.

Where would you place yourself on this ladder? **Fill in the circle that best represents where you would be on this ladder.**



Food Opinions Questionnaire

[Author note: This survey was completed once using the healthy food list and once using the unhealthy food list]

Please rank your top three choices of foods for each of the following situations. You may choose the same food for more than one question. Choose your foods from the drop-down lists—make sure to scroll down to see all the food items in the lists (10 foods in total listed in alphabetical order).

After choosing from the list, please give us more details about the foods you chose, such as the brand, flavor, and type. Please give as much information as you would give to a person who was going to a store to get that food for you.

[For **Unhealthy Food List**]:

Example: almonds: "roasted, no salt almonds" or "Planter's roasted almonds"

Brownie
Cheesecake
Cheetos
Chips
Chocolate
Chocolate chip cookies
Cupcake
Ice cream
Mac n' cheese
Pizza

[For **Healthy Food List**]:

Example: banana: "not yet ripe, green in color" or "very ripe, yellow and spotted"

Apple
Banana
Bell pepper
Carrots
Celery
Clementines
Cucumber
Grapes
Orange
Strawberries

1) What foods do you want to eat right now?

a. First choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

b. Second choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

c. Third choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

2) What foods would make you feel better if you were in a bad mood?

a. First choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

How confident are you that eating that food would make you feel better? (please circle your answer)

1----------2----------3----------4----------5----------6----------7

not at all confident very confident

b. Second choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

How confident are you that eating that food would make you feel better? (please circle your answer)

1----------2----------3----------4----------5----------6----------7

not at all confident very confident

c. Third choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

How confident are you that eating that food would make you feel better? (please circle your answer)

1----------2----------3----------4----------5----------6----------7
not at all confident very confident

3) What foods would you want if you were on-the-go?

a. First choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

How confident are you that you would want that food if you were on-the-go? (please circle your answer)

1----------2----------3----------4----------5----------6----------7
not at all confident very confident

b. Second choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

How confident are you that you would want that food if you were on-the-go? (please circle your answer)

1----------2----------3----------4----------5----------6----------7
not at all confident very confident

c. Third choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

How confident are you that you would want that food if you were on-the-go? (please circle your answer)

1----------2----------3----------4----------5----------6----------7
not at all confident very confident

4) What foods would you want if you were watching a movie?

a. First choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

b. Second choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

c. Third choice: [select from list]

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

Appendix B. Study 1 Lab Day Questionnaires

Hunger Assessment

How hungry are you feeling right now? (1 = *not at all*, 7 = *extremely hungry*)

Modified Thoughts Questionnaire

Please rate each statement as to how often you have thought about that aspect *in the time since you gave your speech and completed the math task.*

0 = Never
1 = Not often
2 = Sometimes
3 = Often
4 = Very often

1. My speech was good (P)
2. I could have done much better (N)
3. How anxious I felt (N)
4. I should have chosen a different topic (N)
5. If my blushing/sweating/dry mouth/shaking was obvious (N)
6. How well I handled it (P)
7. How bad my speech was (N)
8. I made a fool if myself (N)
9. How much I enjoy these situations (P)
10. How I always do badly in this type of situation (N)
11. I must have looked stupid (N)
12. How smoothly it all went (P)
13. How self-conscious I felt (N)
14. What a failure I was (N)
15. That I chose an interesting topic (P)
16. How many mistakes I made (N)
17. How confident I felt (P)
18. I came across as self-assured
19. How awkward I felt (N)
20. That I was at my best (P)
21. How fast my heart was pounding (N)
22. I didn't make a good impression (N)
23. Other aspects of the speech task
24. The overall speech task situation

Note. Items marked with an "N' form the negative rumination subscale. Items marked with a "P" form the positive rumination subscale.

Perceived Stress Scale (14-item)

The questions below ask about your thoughts and feelings during the past month. Indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer each question fairly quickly. That is, don't try to count up the number of times you felt a particular way, but rather, indicate what seems like a reasonable estimate. Please choose from the following 5 responses for each question:

0 = never
1 = almost never
2 = sometimes
3 = fairly often
4 = very often

In the last MONTH:

1. How often have you been upset because of something that happened unexpectedly?
2. How often have you felt that you were unable to control the important things in your life?
3. How often have you felt nervous and stressed?
4. How often have you dealt successfully with irritating life hassles?
5. How often have you felt that you were effectively coping with important changes that were occurring in your life?
6. How often have you felt confident about your ability to handle your personal problems?
7. How often have you felt that things were going your way?
8. How often have you found that you could not cope with all the things that you had to do?
9. How often have you been able to control irritations in your life?
10. How often have you felt that you were on top of things?
11. How often have you been angered because of things that happened that were outside of your control?
12. How often have you found yourself thinking about things that you have to accomplish?
13. How often have you been able to control the way you spend your time?
14. How often have you felt difficulties were piling up so high that you could not overcome them?

Post-Stressor Appraisals

The following statements refer to your thoughts and feelings about the speech and math tasks you have just completed. Please make a clear mark on the scale next to each statement to indicate how much you disagree or agree with each statement.

|_____|

Strongly disagree — Strongly agree

1. I felt in control while performing the tasks. (R)
2. I found the tasks to be challenges that I could handle. (R)
3. I felt threatened while completing the tasks.
4. I felt that the tasks were stressful.
5. I had the energy I needed to perform well on the tasks. (R)
6. I was mentally and emotionally prepared for the tasks. (R)
7. I had enough time to prepare for the tasks. (R)

Comfort Eating Expectations Scale

Please rate how true each statement is for you.

1 = not true at all, 6 = extremely true

1. When I'm upset all I need is one of my favorite foods to calm me down.
2. No type of food can get me out of a bad mood. (R)
3. At the end of a stressful day, I can count on my favorite food to help me relax.
4. Eating a good meal when I'm down always puts me in a better mood.
5. When I'm feeling anxious, even my favorite foods do not make me feel better. (R)
6. Enjoying a tasty meal or snack helps me take my mind off of my worries.

Appendix C. Study 2 Pre-Questionnaires

Center for Epidemiological Studies Depression Scale

Below is a list of ways you might have felt or behaved. Please indicate how often you have felt this way DURING THE PAST 7 DAYS on a scale from 0-3:

0 = Rarely or None of the time (less than 1 day)
1 = Some or a Little of the time (1-2 days)
2 = Occasionally or a Moderate amount of time (3-4 days)
3 = Most or All of the time (5-7 days)

1. I was bothered by things that usually don't bother me
2. I did not feel like eating; my appetite was poor
3. I felt that I could not shake off the blues even with help from my family or friends
4. I felt that I was just as good as other people
5. I had trouble keeping my mind on what I was doing
6. I felt depressed
7. I felt that everything I did was an effort
8. I felt hopeful about the future
9. I thought my life had been a failure
10. I felt fearful
11. My sleep was restless
12. I was happy
13. I talked less than usual
14. I felt lonely
15. People were unfriendly
16. I enjoyed life
17. I had crying spells
18. I felt sad
19. I felt that people disliked me
20. I could not get "going"

Note. This survey was also administered on Day 15 (post-intervention).

Demographic Questionnaire

Please complete the following personal information:

1. Sex: M F

2. Age _____

3. What is your racial/ethnic heritage?
    a. White/Anglo or European American
    b. Black/African American, Carribean
    c. Asian, Asian American, Pacific Islander
    d. Hispanic/Latino(a)
    e. Native American
    f. Arabic/Middle Eastern
    g. Bi-racial
        i. _____
        ii. _____
    h. Other
        i. _____

4. Do you have a history of an eating disorder? Y N

5. Do you have a history of substance abuse? Y N

6. Are you on a strict diet? Y N

7. Do you have any food/beverage allergies? Y N

    a. What are your food/beverage allergies? _____

8. Is English your primary language? Y N

    a. If not, are you fluent in English? Y N

9. Do you have any current major illness or injury? Y N

10. Do you have any current diagnosed psychiatric condition (e.g., bipolar disorder)?

    Y N

11. Do you have a smartphone with the ability to connect to the Internet and download apps?

    Y N

12. Please indicate the number choice below that you feel was most representative of your family's annual household income when you were growing up:

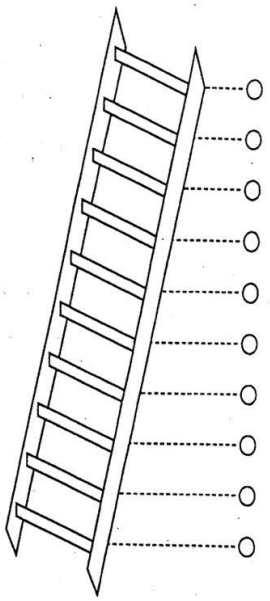
a. less than $10,000
b. $ 10,000-$19,999
c. $ 20,000-$29,999
d. $30,000-$39,999
e. $40,000-$49,999
f. $50,000-$59,999
g. $60,000-$69,999
h. $70,000-$79,999
i. $80,000-$89,999
j. $90,000-$99,999
k. $100,000-$124,999
l. $125,000-$149,999
m. greater than $150,000

19.

1a. Imagine that this ladder pictures how American society is set up.

- At the top of the ladder are the people who are the best off--they have the most money, the highest amount of schooling, and the jobs that bring the most respect.
- At the bottom are people who are the worst off--they have the least money, little or no education, no job or jobs that no one wants or respects.

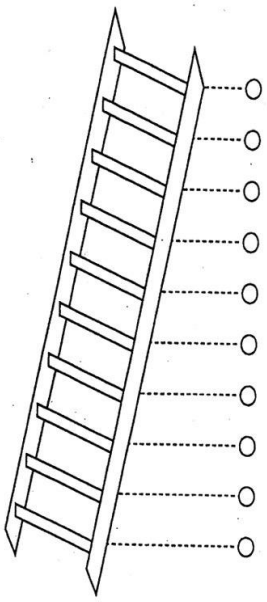
Now think about your family. Please tell us where you think your family would be on this ladder. **Fill in the circle that best represents where your family would be on this ladder.**



1b. Now assume that the ladder is a way of picturing your school.

- At the top of the ladder are the people in your school with the most respect, the highest grades, and the highest standing.
- At the bottom are the people who no one respects, no one wants to hang around with, and have the worst grades.

Where would you place yourself on this ladder? **Fill in the circle that best represents where you would be on this ladder.**



Modified Food Opinions Survey

Please rank your top three choices of foods for each of the following situations. You may choose the same food for more than one question. After identifying a food, please give us more details about it, such as the brand, flavor, and type, if appropriate. Please give as much information as you would give to a person who was going to a store to get that food for you.

1. What foods do you want to eat right now?

a. First choice:

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

b. Second choice:

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

c. Third choice:

Please tell us more about that food. What flavor, brand, and/or type of that item would you want?

2. What foods would make you feel better if you were stressed?

a. First choice:

How confident are you that eating that food would make you feel better? (please circle your answer)

1----------2----------3----------4----------5----------6----------7

not at all confident very confident

b. Second choice:

How confident are you that eating that food would make you feel better? (please circle your answer)

1----------2----------3----------4----------5----------6----------7

not at all confident very confident

c. Third choice:

How confident are you that eating that food would make you feel better? (please circle your answer)

1----------2----------3----------4----------5----------6----------7
not at all confident very confident

3. What foods would you want if you were on-the-go?

a. First choice:

How confident are you that you would want that food if you were on-the-go? (please circle your answer)

1----------2----------3----------4----------5----------6----------7
not at all confident very confident

b. Second choice:

How confident are you that you would want that food if you were on-the-go? (please circle your answer)

1----------2----------3----------4----------5----------6----------7
not at all confident very confident

c. Third choice:

How confident are you that you would want that food if you were on-the-go? (please circle your answer)

1----------2----------3----------4----------5----------6----------7
not at all confident very confident

Food Dimensions Survey

For each of the following food items, first indicate whether or not you have ever tasted the food before (Yes/No). If yes, then rate the food on a sliding scale from "not at all" to "extremely" for each of the following characteristics:

a) familiar
b) sweet
c) pleasant
d) sour
e) bitter
f) how likely is it that you will buy this food in the future?

|_____ 100-point sliding scale _____|

Not at all Extremely

1. Apple
2. Apricots
3. Banana
4. Blueberries
5. Cantaloupe
6. Cherries
7. Clementines
8. Grapes
9. Honeydew
10. Kiwi
11. Mango
12. Nectarines
13. Orange
14. Peaches
15. Pears
16. Pineapple
17. Plums
18. Pomegranate
19. Star fruit
20. Strawberries

Note. This survey was also administered on Day 15 (post-intervention).

Perceived Stress Scale (10-item)

The questions below ask about your thoughts and feelings during the past month. Indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer each question fairly quickly. That is, don't try to count up the number of times you felt a particular way, but rather, indicate what seems like a reasonable estimate. Please choose from the following 5 responses for each question:

0 = never
1 = almost never
2 = sometimes
3 = fairly often
4 = very often

In the last 7 DAYS:

1. How often have you been upset because of something that happened unexpectedly?
2. How often have you felt that you were unable to control the important things in your life?
3. How often have you felt nervous and stressed?
4. How often have you felt confident about your ability to handle your personal problems?
5. How often have you felt that things were going your way?
6. How often have you found that you could not cope with all the things that you had to do?
7. How often have you been able to control irritations in your life?
8. How often have you felt that you were on top of things?
9. How often have you been angered because of things that happened that were outside of your control?
10. How often have you felt difficulties were piling up so high that you could not overcome them?

Note. This survey was also administered on Day 15 (post-intervention).

Progressive Muscle Relaxation Run-In Item

Please answer the following questions about the activity you just engaged in:

1. Rate how much you liked or disliked engaging in this activity:

   1 = disliked it a lot
   2 = disliked it a moderate amount
   3 = disliked it a little
   4 = liked it a little
   5 = liked it a moderate amount
   6 = liked it a lot

2. Which of these phrases was included in the recording that you just listened to?

A. "Place one hand on your heart and one hand on your belly, and notice the sensations in your body as you inhale and exhale . . ."

B. "Imagine the scent of freshly cut grass on a sunny spring day, with clear blue skies and the sounds of birds singing nearby . . ."

C. "Take a brief moment to set an intention for the next 6 minutes. For example, you might dedicate this time to find gratitude, forgiveness, or self-compassion in your life. . ."

D. "You can relax even more deeply by going to a place that's most peaceful for you . . . a place where you feel relaxed and calm . . ."

E. "Imagine your immune system working to heal any aches in your body . . . picture the cells you need going to the places they need to go . . ."

Appendix D. Study 2 Lab Questionnaires

Hunger Assessment

1. How hungry are you feeling right now? (1 = *not at all*, 7 = *extremely hungry*)
2. When was the last time that you had something to eat? ____ : ____ AM/PM

Positive and Negative Affect Schedule

The following is a list of words that describe different feelings and emotions. For each item, indicate to what extent you feel this way right now at the present moment, on a scale from 1-5:

1 = very slightly or not at al
2 = a little
3 = moderate
4 = quite a bit
5 = extremely

1. Interested
2. Distressed
3. Excited
4. Upset
5. Strong
6. Guilty
7. Scared
8. Hostile
9. Enthusiastic
10. Proud
11. Irritable
12. Alert
13. Ashamed
14. Inspired
15. Nervous
16. Determined
17. Attentive
18. Jittery
19. Active
20. Afraid
21. Happy
22. Sad
23. Stressed
24. Calm
25. Tense
26. Relaxed

Progressive Muscle Relaxation Exit Survey

Please think back on your experience with the progressive muscle relaxation activity, and rate how true each statement is for you.

1 = not true at all, 6 = extremely true

1. I enjoyed engaging in this activity.
2. I would recommend this activity to others.
3. This activity took too much time out of my day. (R)
4. This activity was easy to incorporate in my daily routine.
5. This activity made me feel relaxed.
6. I would use this activity as a stress reduction technique in the future.
7. I completed this activity the number of times that I was instructed to.

Appendix E. Study 2 Post-Intervention Home Questionnaires

Brief Diary Questionnaire

1. How stressful was your day, overall? 1 = not at all; 7 = extremely
2. Around what time of day did you feel most stressed? ___:___ AM/PM
3. How enjoyable was your day, overall? 1 = not at all; 7 = extremely
4. How tired did you feel today, overall? 1 = not at all; 7 = extremely
5. How many hours of sleep did you get last night? ___ hours

Comfort Eating Expectations Scale

Please rate how true each statement is for you.

1 = not true at all, 6 = extremely true

1. When I'm upset all I need is one of my favorite foods to calm me down.
2. No type of food can get me out of a bad mood. (R)
3. At the end of a stressful day, I can count on my favorite food to help me relax.
4. Eating a good meal when I'm down always puts me in a better mood.
5. Enjoying a tasty meal or snack helps me take my mind off of my worries.

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