Dietary restraint and stress-induced alterations in eating: Exploring the role of heart rate variability as a proxy for self-regulation, attentional bias, and perceived safety

by

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Abstract

Restraint theory posits that the capacity to successfully diet is cognitively demanding, requiring exertion of cognitive control over eating. Demands that deplete this limited inner resource (e.g., stress) can thus lead restrained eaters to become disinhibited and consume large amounts of food. This program of research aimed to objectively investigate the causal role of self-regulation in restrained eaters' disinhibition. As a robust literature indicates that higher heart rate variability (HRV) indexes self-regulatory capacity, HRV was used to quantify changes in self-regulation. Study One explored whether HRV mediated disinhibition in 93 female undergraduates exposed to a laboratory stressor and subsequent bogus taste test. Though HRV significantly mediated the link between the stressor and food intake, the stress-induced reduction in HRV was associated with decreased intake. Dietary restraint also moderated the pathway between HRV and intake, such that the indirect effect of stress on intake via HRV was only significant for less restrained eaters, but restrained eaters did not show evidence of disinhibition. In a subsequent study of 147 females, Study Two examined whether a serial mediation via HRV and attentional bias to food accounted for these unexpected findings. It was predicted low HRV may attenuate attentional bias to food and reduce intake in less restrained eaters while it would enhance attentional bias to food and intake in more restrained eaters. It was further posited that the model would only emerge for those uncertain about safety from additional stress. None of the hypotheses were supported. However, an exploratory moderated serial mediation revealed sympathetic nervous system activity led to a significant reduction in hunger that attenuated intake for less restrained eaters uncertain about their safety. Although hunger among more restrained eaters similarly decreased, they did not reduce their intake. Overall, these findings imply restrained eaters show a disconnect from internal physiological cues that may facilitate disordered eating when stressed.

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Chapter 1. Introduction

Restrained eaters often exhibit alternating periods of attempting to control their food intake interspersed with bouts of overeating, commonly referred to as disinhibited eating (Polivy et al., 2020). This pattern arguably mirrors clinically-relevant binge-restrict cycles among those with diagnosable eating disorders (Fairburn, 2008). In light of this compelling parallel, there is significant impetus to understand the mechanisms through which restraint may prompt disinhibited eating. A number of factors prompt disinhibited eating (see Stroebe, 2008). Though theories such as restraint theory (Herman & Mack, 1975; Herman & Polivy, 1975) and the process model of ego depletion (Geisler et al., 2016) have been advanced to explain how dietary restraint may lead to disinhibition, a simple explanation of the causal mechanisms underlying this phenomenon remains to be elucidated (Coletta et al., 2009; Lowe & Kral, 2006). While it is posited that self-regulation may be a key factor in predicting disinhibition (Johnson et al., 2012; Schaumberg et al., 2016), this conjecture has yet to be tested in an experimental study capable of elucidating this causal pathway. The overall aim of this program of research was thus to objectively investigate the causal role of self-regulation in restrained eaters' disinhibition.

1.1 Defining Restrained Eating

Restrained eating refers to intentional efforts to restrict one's food intake with the goal of controlling one's bodyweight (Stroebe, 2008), characterizing an eating style that is under cognitive, rather than physiological control (Johnson et al., 2012). While it may seem as though such efforts would be an effective strategy for weight maintenance, a large body of literature suggests otherwise. Dietary restraint has been shown to result in counterregulatory, disinhibited eating in situations where individuals' cognitive control over their food intake is undermined (Johnson et al., 2012). Relevant to this discussion is Herman and Polivy's (1983) boundary model, which strives to account for physiological and non-physiological determinants of eating. At the crux of this model, it is suggested that under normative conditions, homeostatic mechanisms regulate one's eating by maintaining it within an upper and lower boundary corresponding to satiety and hunger, respectively (Herman & Polivy, 1983). Between these two endpoints, termed the "range of biological indifference," an organism will not be prompted to seek out food, as there is no hunger to remedy. If consumption is not sufficient to maintain satiety in this range, however, the individual will fall below the hunger boundary, which will thereby prompt eating. It is within the range of biological indifference that restraint is proposed to operate to regulate individuals' food consumption (Herman & Polivy, 1983).

Restrained eaters impose a cognitively mediated diet boundary that falls below their physiological satiety boundary in an attempt to promote a negative energy balance, either to achieve weight loss or suppress their weight below their biological set-point weight (Herman & Polivy, 1983). Restrained eaters are consequently expected to eat less than their unrestrained counterparts in situations where they are able to successfully exert cognitive control over their eating. If this cognitive control is disrupted, however, restrained eaters will eat towards the boundary for satiety as one naturally would when eating is under homeostatic control. Moreover, Herman and Polivy (1983) note the satiety boundary seems to be displaced further outward in restrained compared to unrestrained eaters, such that they require greater consumption to reach a perceived state of satiety when restriction is disrupted. It is proposed that this accounts for their excessive consumption upon disinhibition. Though this hypothesized shift in the boundary of satiety was initially theoretical, there is evidence that continual caloric restriction impacts the hormones responsible for regulating appetite in a manner that could alter physiological satiety (Culbert et al., 2016). For example, the appetite-stimulating hormone ghrelin increases during short-term fasting, regardless of body adiposity (Atalayer et al., 2013) and it is elevated among those with anorexia nervosa and bulimia nervosa (Culbert et al., 2016), eating disorders both characterized by dietary restriction and restraint to varying degrees. This could suggest episodes of disinhibited eating may be attributable to homeostatic changes that occur in an attempt to restore negative energy balance and return to the range of biological indifference, which may consequently override restrained eaters' cognitive control over their food intake. While this is an appealing explanation, evidence suggests that individuals who endorse high dietary restraint may not necessarily be physiologically deprived (Stice et al., 2007).

1.1.1 *Restrained Eating versus Restriction*

Despite restrained eaters' efforts to restrain their food intake, research indicates that dietary restraint as assessed via current self-report measures does not appear to correlate with individuals' actual energy intake, or dietary *restriction*, per se (e.g., Stice et al., 2004, 2007). That is, when examining overall trends, individuals who score more highly on measures of restrained eating do not eat less than those reporting lower restraint across both short-term (i.e., Stice et al., 2004) and long-term (i.e., Stice et al., 2007) assessments. Dietary restraint may thus be thought to capture *cognitive* efforts to restrict intake, regardless of the *behavioural* success of these efforts (Schaumberg et al., 2016). In accordance, restraint as it is currently operationalized should not be viewed as completely synonymous with caloric restriction. This key distinction between intention to restrain intake and engagement in actual restraint behaviours may help to explain heterogeneous findings in the literature with regards to restrained eaters' capacity to consistently achieve and maintain a true caloric deficit.

To explore this possibility, Rodgers et al. (2018) divided the Dutch Eating Behaviour Questionnaire – Restrained Eating scale (DEBQ-R) into items pertaining to intent for restraint (e.g., *Do you try to eat less at mealtimes than you would like to eat?*) and actual restraint (e.g., *If you have put on weight, do you eat less than you usually do?*). Over a 7-day period, trait restraint behaviour, but not restraint intentions, consistently predicted daily restraint behaviour. However, trait restraint intentions predicted daily overeating. Paradoxically, deliberate cognitive efforts or intentions to restrict intake might lead to a preference for palatable food in anticipation of deprivation (Rodgers et al., 2018). Schaumberg et al. (2016) similarly posit that what might be critical for restrained eaters is their *perceived* level of deprivation, which may or may not accord with actual physiological deprivation. Empirical evidence appears to substantiate such a notion.

Among chronic, intermittent dieters, Presnell et al. (2008) found that those instructed to engage in naturalistic dieting did not lose weight, while those in the non-dieting condition gained weight. This may suggest individuals who report higher restraint eat less than they would desire, despite not achieving a significant deficit in energy intake compared to their daily energy expenditure (i.e., a caloric deficit). Further of note, Stice et al. (2007) found those who endorsed elevated restraint were more likely to underreport their caloric intake. Although underreporting could reflect social desirability bias given concerns around eating, Presnell et al.'s (2008) findings suggest another explanation. Restrained eaters' underreporting could suggest they perceive a greater sense of deprivation that may lead them to feel they are eating less than they are in actuality. These findings implicate that, on the whole, restrained eaters may have strong intentions to restrain their eating in the absence of a negative energy balance. As such, rather than reflecting an opposing response to physiological deprivation, disinhibited eating might be most cogently understood as a response to factors that interfere with their intentions to restrict.

1.1.2 *Prompting Factors in Restrained Eaters' Disinhibition*

Restrained eaters' disinhibition occurs following various experimental tasks, whereby individuals who exhibit higher dietary restraint engage in consumption beyond that exhibited by their less restrained counterparts (Boyce & Kuijer, 2014; Polivy & Herman, 1985; Stroebe, 2008; Wallis & Hetherington, 2004). Factors commonly documented to disinhibit restraint include the transgression of one's diet boundary (e.g., Herman & Mack, 1975), induction of negative affect (e.g., Fay & Finlayson, 2011) or stress (e.g., Tanofsky-Kraff et al., 2000), and imposition of a cognitive load (e.g., Boon et al., 2002; Lattimore & Maxwell, 2004). One of the seminal manipulations shown to elicit disinhibition was the preload paradigm wherein individuals consume a predefined amount of a food that would typically be forbidden for restrained eaters (e.g., a milkshake) to violate their dietary boundary prior to ad libitum exposure to food (Herman & Mack, 1975). Under preload conditions, restrained eaters reliably consume more food during subsequent ad libitum exposure, while unrestrained eaters reduce their intake as might be expected given homeostatic regulation based on satiety (Stroebe, 2008). When restrained eaters' dietary rules have been broken, either with respect to the types and/or amount of foods allowed, they may eat to satisfy their normally restricted cravings in a phenomenon deemed the "what-the-hell" effect (Herman & Polivy, 1983). Nevertheless, the preload paradigm only suggests that restrained eaters' overeating is potentiated by physiological or psychological factors once their dietary rules have already been broken rather than indicating that these factors causally trigger disinhibition and overconsumption of palatable foods, per se.

Tasks that do not force restrained eaters to break dietary rules can also lead to disinhibited eating. Wallis and Hetherington (2004) found that individuals high on restraint and low on emotional eating consumed significantly more chocolate after both an ego-threatening Stroop task (i.e., including emotional words) and an incongruent Stroop task compared to a control condition. Although both tasks were rated as significantly more stressful than the control, perceived stress ratings fell below the midpoint of the scale. However, there was a positive correlation between reaction time and intake across all conditions for those with high restraint (Wallis & Hetherington, 2004). As reaction time on the Stroop provides an index of task difficulty (Lattimore & Maxwell, 2004), the extent to which the task taxed restrained eaters' cognitive resources may have played a role in triggering disinhibition (Wallis & Hetherington, 2004). Additional studies suggest disinhibited eating is also prompted by tasks that present a personally-relevant challenge requiring effortful control.

Boyce and Kuijer (2014) found that those who endorsed higher restraint ate significantly more sweet food in a taste test after exposure to media images of thin models. However, the effect only occurred for restrained eaters in the advertent exposure condition which required participants to concentrate on the images under the guise that they would need to complete a subsequent memory test. Disinhibition was absent when the thin images were inadvertently presented on a computer beside them as they completed questionnaires. The authors concluded that the degree of attention and effort allocated to the images was crucial in prompting eating (Boyce & Kuijer, 2014). As restrained eaters tend to be highly invested in their body image and report high levels of social comparison, thin-ideal awareness, and thin-ideal internalization (Boyce & Kuijer, 2014), viewing thin images in a focused manner may have heightened the threat to their own body image. As illustrated by the aforementioned findings, a diverse range of manipulations prompt disinhibited eating. In light of these varying manipulations, a number of theories and models have been advanced to explain why restrained eaters may overindulge.

1.1.3 *Theories of Restrained Eaters' Disinhibition*

The central theories formulated or applied to explain disinhibition among restrained eaters include restraint theory (Herman & Mack, 1975) and the process model of ego depletion (Geisler et al., 2016). The pioneering and most widely cited is restraint theory. As per restraint theory (Herman & Mack, 1975), the capacity to successfully diet is cognitively demanding, requiring attention and exertion of cognitive control over one's eating (Boyce & Kuijer, 2014). Demands placed on one's cognitive capacity or any factor that may disinhibit behaviour (e.g., alcohol) may thus cause a breakdown of control, thereby disrupting their characteristic restraint and releasing their suppressed eating (Polivy & Herman, 1985). Restraint theory traditionally posited negative affect or stress were the central disinhibitors that led to restrained eaters' situationally-induced overeating (Polivy & Herman, 1999). This explanation has been called into question (e.g., Lowe & Kral, 2006), however, as self-reported negative affect or stress has not been consistently demonstrated in circumstances that elicit disinhibition and cognitive load can also upset maintenance of restraint. Nevertheless, a lack of self-reported stress does not necessarily equate to a lack of physiological stress.

Redundancy analyses examining the coherence between self-reported affect and a multivariate set of autonomic variables (e.g., cardiac inter-beat interval, respiratory sinus arrhythmia, cardiac pre-ejection period, left ventricular ejection time, stroke volume, blood pressure, etc.) found only approximately 21.6% to 32.1% of the variance in the physiological variables predicted variance in affective self-reports (Friedman et al., 2014). These findings imply that one can experience stress on a physiological level despite low self-reported, subjectively perceived stress. Coping with stress also necessitates cognitive resources that may increase cognitive load (Stroebe et al., 2013), suggesting that stress or negative affect and cognitive load may not be as divergent as previously put forth. Thus, in spite of arguments levied against the key role of negative affect or stress in prompting disinhibition (i.e., Boon et al., 2002; Loth et al., 2016; Lowe & Kral, 2006; Stroebe, 2008), such conclusions may be premature. Another explanatory model put forth is the process model of ego depletion (Geisler et al., 2016; Inzlicht & Schmeichel, 2012).

Ego depletion has been defined as, "...the state of diminished resources following exertion of self-control" (Baumeister et al., 2007, p.352). The process model of ego depletion suggests ego depletion is characterized by a shift in both motivational orientation and attentional focus (Inzlicht & Schmeichel, 2012). More specifically, it is postulated that one's motivational orientation shifts away from the suppression of desires towards their gratification, while attention shifts from cues that signal control to those that signal gratification (Inzlicht & Schmeichel, 2012). As applied to restrained eaters, Geisler et al. (2016) propose a state of ego depletion would lead to greater motivation to gratify eating desires, rather than maintain one's diet, and enhanced attention to palatable food. Though on the surface this model seems to make divergent claims from that of restraint theory vis-à-vis the core factor eliciting disinhibition, ego depletion can likewise induce a negative affective state (Hagger et al., 2010). In accordance, the process model of ego depletion makes similar assertions as restraint theory, though it provides a more nuanced view as to how certain factors and situations may lead to restrained eaters' disinhibition.

Despite these existent theories, it has been argued that a parsimonious explanation of the mechanism underlying this disinhibition phenomenon in restrained eaters is still lacking (Coletta et al., 2009; Lowe & Kral, 2006). Arguably, the aforesaid theoretical explanations converge on the notion that effortful self-control or self-regulation is critical to maintain one's restraint. When a conflict or cognitive demand arises that challenges restrained eaters' control over their intake or undermines self-regulatory capacity in some way, a breakdown of impulse control may occur and lead to overconsumption of palatable, tempting foods that may often be off-limits. This may be most parsimoniously subsumed under the overarching framework of the resource depletion model of self-control, which posits cognitively taxing self-regulatory tasks diminish self-control, thereby impeding subsequent efforts to control one's eating (Loth et al., 2016). While self-control or self-regulation appears to be implicated in prompting restrained eaters' disinhibition from a theoretical standpoint, there is a lack of causal evidence to support this notion at present.

In addition to multiple theories that seek to explain restraint, a myriad of questionnaires exist to measure restraint. Divergence in the operationalization and conceptualization of restraint across such questionnaires may further complicate efforts to consistently predict and explain this phenomenon. Recent attempts have been made to identify the core elements that might underlie these various measures. Of interest, such analyses similarly point towards the role of self-regulation and its disruption in leading to disinhibited eating (Hagan et al., 2017).

1.1.4 *Self-Regulation and Restrained Eating*

Hagan et al. (2017) recently conducted exploratory and confirmatory factor analyses to identify latent factors across the most frequently used measures of dietary restraint in the literature. These measures included: the Revised Restraint Scale (RS; Herman & Polivy, 1975), Three-Factor Eating Questionnaire – Restraint scale (TFEQ-R; Stunkard & Messick, 1985), Eating Disorder Examination-Questionnaire – Restraint subscale (EDE-Q-R; Fairburn & Bèglin, 1994), Eating Disorder Inventory-3 – Drive for Thinness scale (EDI-3 – DT; Garner, 2004), and the Dutch Eating Behaviour Questionnaire – Restrained Eating scale (DEBQ-R; van Strien et al., 1986). It was suggested that one reason for heterogeneity in conceptualizations as to what leads to disinhibition may be that the measures that have been used to operationalize dietary restraint across such studies are heterogeneous in what they ultimately assess.

Analyses revealed that dietary restraint appears to contain three factors: (a) Calorie Counting (e.g., monitoring caloric intake; adherence to calorie limits; choosing low-calorie foods); (b) Preoccupation with Dieting (e.g., fear of weight gain; preoccupation with dieting and weight; anxiety surrounding consumption of forbidden foods); and (c) Weight-Focused Restraint (e.g., attempts to eat less for the purposes of influencing weight or shape). While eating disorder risk was significantly and positively associated with all factors, higher body mass index (BMI) and binge eating were only significantly associated with greater Preoccupation with Dieting and Weight-Focused Restraint while Calorie Counting did not exhibit a significant relationship with BMI or binge eating (Hagan et al., 2017). Associations between restraint and disinhibited eating may thus be more nuanced than initially proposed. To return to the earlier distinction between restraint behaviours and intentions, it would appear as though Hagan et al.'s (2017) Calorie Counting factor reflects the implementation of restraint behaviours, whereas Preoccupation with Dieting and Weight-Focused Restraint predominantly signify cognitive intentions for restraint. Endorsement of actively engaging in restraint behaviours may indicate such individuals are better able to control their urges to consume tempting foods and flexibly self-regulate.

Recent studies have likewise begun to highlight that not all restrained eaters appear vulnerable to this disinhibition effect (e.g., Johnson et al., 2012; Schaumberg et al., 2016). Literature to date has proposed self-regulation may be a crucial factor differentiating those who engage in harmful restraint (i.e., leading to disordered eating) versus effective restraint (i.e., producing weight loss; Schaumberg et al., 2016). Behavioural elements of self-regulation posited to promote healthy dieting include self-monitoring, self-evaluation, and self-reinforcement. Hagan et al. (2017) suggest their three-factor solution of restraint reinforces the importance of self-regulation in predicting unsuccessful restraint, whereby calorie counting may serve as a means to effectively self-regulate. Indirect evidence also suggests restrained eaters who become disinhibited ("unsuccessful restrained eaters") exhibit a reduced capacity for self-regulation. For example, among female restrained eaters, Keller and Siegrist (2014) found higher self-reported dispositional self-control was associated with a BMI in the normal-weight range, whereas lower self-control was related to a BMI in the overweight range. Neuroimaging studies have additionally shown that regions implicated in cognitive control and conflict monitoring exhibit weaker connectivity in unsuccessful relative to successful restrained eaters (Zhang et al., 2020). Taken together, various findings and theories implicate that self-regulation may be critical in the maintenance of restrained eaters' restraint intentions and avoidance of disinhibition.

While the aforementioned self-regulatory abilities associated with successful dieting such as self-monitoring, self-evaluation, and self-reinforcement may play a role in long-term weight control, self-regulation processes may arguably operate on a more reactive micro-level and factor into the success of weight control long-term as well. As alluded to above, stressful or challenging tasks that lead restrained eaters to become disinhibited (e.g., Stroebe, 2008) may require self-regulation based on the parameters or demands of such tasks, which may disrupt subsequent self-regulation when exposed to palatable foods. To date, however, restrained eaters' self-regulation has merely been inferred to play a role in this phenomenon. No studies have measured whether restrained eaters experience a reduction in their self-regulatory capacity prior to disinhibited eating, even from individuals' own subjective self-report. Examining self-regulation objectively rather than subjectively via self-report offers several advantages in this context.

1.1.5 *Objective Assessment of Self-Regulation*

Whereas self-report is vulnerable to reporting biases (e.g., social desirability), objective measurements are less amenable to conscious manipulation and can more accurately depict participants' functioning from an affective, cognitive, behavioural or biological perspective (Smith et al., 2019). Use of objective psychophysiological parameters can also reveal relevant processes that occur beyond conscious awareness and capture constructs that may fluctuate on an ongoing basis (Smith et al., 2019), such as one's momentary capacity for self-regulation. Perhaps most importantly, passively collecting objective psychophysiological data can reveal a more fine-grained temporal pattern of behaviour (Smith et al., 2019) and avoid apprising individuals of the construct under study. Requiring participants to self-report their self-regulatory capacity in this context might interfere with the validity of the study by priming restrained eaters with concepts related to self-control, which could alter their subsequent eating behaviour (Pollert & Veilleux, 2018). As a consequence, there appears to be value in striving to objectively examine how self-regulatory processes may provoke disinhibited eating among restrained eaters in response to a stressful, cognitively demanding, ego-depleting task. Heart rate variability (HRV) offers a robust neurophysiological index that may be able to objectively assess self-regulatory capacity in this context (Holzman & Bridgett, 2017; Zahn et al., 2016).

1.2 Heart Rate Variability (HRV)

The autonomic nervous system (ANS) is comprised of two complementary branches: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The SNS is responsible for energy mobilization and the fight-or-flight response, whereas the PNS prompts restoration and relaxation (Thayer et al., 2009). The SNS and PNS interact in a largely antagonistic manner to produce appropriate physiological arousal in response to the environment (Appelhans & Luecken, 2006). With regards to heart rate (HR), the interplay between the SNS's and PNS's outputs on the sinoatrial node produce the complex beat-to-beat variability of healthy individuals (Thayer & Lane, 2000). The sinoatrial node is the primary pacemaker responsible for regulating heartbeat by producing the electrical action potentials that cause heart contractions (Appelhans & Luecken, 2006), a process primarily controlled by the tenth cranial nerve (i.e., the vagus nerve; Porges & Furman, 2011). It is important to note that the SNS and PNS differ vis-à-vis the mechanism, and thus the time course, in which they impact one's HR.

Due to the differential temporal kinetics of autonomic neuroeffectors, SNS influences on the cardiovascular system are relatively slow, occurring in the order of magnitude of seconds, whereas PNS influences incited by the vagus nerve occur in the realm of milliseconds (Thayer & Lane, 2000; Thayer et al., 2012). Specifically, the SNS's influence on HR, which is mediated by norepinephrine, possesses a slower course of action on cardiac function that typically reaches a peak effect after about 4 s (Appelhans & Luecken, 2006). By contrast, the PNS's regulation of HR, controlled by the neurotransmission of acetylcholine, is able to have a peak effect within 0.5 s and can return to its baseline within 1 s (Appelhans & Luecken, 2006). The capacity of the PNS to alter cardiac activity more rapidly enables greater flexibility in responding to environmental demands (Appelhans & Luecken, 2006). This flexibility poses an advantage for organisms that must react to the everchanging landscape of their milieu and thus translates into a greater proficiency to survive. As SNS activation also demands more energy, resting cardiac autonomic balance favours dominant PNS influence to promote energy conservation (Porges, 1995).

As a consequence of this preferred autonomic balance, resting HR is under inhibitory control of the vagus via the PNS, which keeps HR lower than the intrinsic rate of the sinoatrial node alone (Appelhans & Luecken, 2006; Thayer et al., 2009). Dominant PNS activity maintains lower physiological arousal and functionally maintains a calm state (Porges & Furman, 2011). Under physical or psychological stress, withdrawal of vagal tone to the heart, reflecting a decrease of PNS inhibition, allows HR to rapidly increase to facilitate arousal (Porges & Furman, 2011). Following vagal withdrawal, the SNS may subsequently become dominant to elicit a sustained increase in HR and produce further arousal to respond to the challenge (Appelhans & Luecken, 2006). The relative ease with which one can transition between states of high and low arousal depends on the flexibility of an individual's ANS to rapidly vary one's HR (Appelhans & Luecken, 2006). A convenient way to capture the ANS's flexibility is via HRV.

HRV is a biomarker for the coordinated activity of the SNS and PNS, and specifically refers to variation in the inter-beat interval (IBI) of one's HR (Shaffer & Ginsberg, 2017). Relative SNS activation shortens the time between heart beats due to correspondent increases in HR, whereas PNS activation causes the IBI to become longer due to decreases in HR (Thayer et al. 2012). Owing to the ability of the PNS to elicit greater beat-to-beat variability over a short time scale, higher HRV thus provides an index that is reflective of dominant PNS activity on the heart (Laborde et al., 2017). Two major theories of HRV have been expounded which relate autonomic flexibility, as captured by HRV, with the capacity for self-regulation and adaptive emotional and behavioural responding: Porges' (1995) polyvagal theory and the neurovisceral integration model of Thayer and colleagues (Thayer & Lane, 2000; Thayer et al., 2012).

1.2.1 *Polyvagal Theory*

Porges' (1995) polyvagal theory notes that, owing to evolutionary forces, mammals' physiology has evolved to have two vagal systems in order to react adaptively to environmental challenges and maintain visceral homeostasis (Porges, 2003). As such, mammals possess both a neo-mammalian system and a more primitive and vegetative "reptilian" system, each of which originates in different medullary brainstem nuclei (Porges, 1995). Humans are thus polyvagal. In mammals, the nucleus ambiguus provides the primary vagal innervation to control the supradiaphragmatic target organs, which include the soft palate, pharynx, larynx, esophagus, bronchi, and heart. Due to myelination of this pathway, the nucleus ambiguus can rapidly adjust metabolic output by regulating HR via the sinoatrial node (Porges et al., 1996). The phylogenetically older unmyelinated vagal system is controlled by the dorsal motor nucleus of the vagus, which has minimal impact on cardiac output in most conditions (Porges et al., 1996).

Nucleus ambiguus vagal tone has two roles (Porges et al., 1996). First, in contexts that pose low environmental demand, high vagal tone facilitates physiological homeostasis to enable growth and restoration. Under such conditions, the vagus acts as a brake that regulates cardiac and metabolic output (Porges & Furman, 2011) and increases inhibitory vagal control of the heart to support social engagement behaviour (Porges, 2007a). To promote survival, however, mammals must be able to evaluate the safety of their milieu and react to stressors or challenges (Porges, 2003). During states characterized by greater environmental challenge and metabolic demand, the “vagal brake” is transiently withdrawn to reduce vagal inhibition on the sinoatrial node. Vagal withdrawal increases HR and can facilitate expression of the SNS, thereby promoting mobilization of the fight-or-flight system or death-feigning behaviours (Porges, 1995; Porges, 2011). Polyvagal theory proposes each branch of the vagus nerve supports a different adaptive behavioural strategy via three phylogenetically-ordered neural circuits behaviourally linked to social communication, mobilization, and immobilization (Porges, 2003).

The crux of polyvagal theory is the proposition that successful adaptation depends upon systematic and reliable withdrawal and reinstatement of the “vagal brake” to regulate metabolic output in the face of constantly changing environmental demands (Porges, 1995). In accordance, during states of stress, vagal withdrawal and decreases in PNS activity are apparent, as reflected by decreased HRV (Porges, 2003; Porges, 2007b). In light of the emphasis on regulating one’s responses to a challenge, polyvagal theory may help to understand restrained eaters’ response to laboratory tasks preceding disinhibition. It would be reasonable to anticipate that the type of stressful or demanding tasks that prompt disinhibition elicit vagal withdrawal to facilitate adaptive responding. The neurovisceral integration model (Thayer & Lane, 2000; Thayer et al., 2012) offers insight into how this may subsequently impact restrained eaters' responses to food.

1.2.2 *The Neurovisceral Integration Model*

The neurovisceral integration model was originally formulated to account for the observed interrelation between individuals' peripheral physiology, cognitive performance, and emotional and physical health (R. Smith et al., 2017). The model acknowledges that an organism's adaptation to environmental challenges is shaped by physiological, behavioural, affective, cognitive, social, and environmental factors (Thayer et al., 2012). Flexibility within changing physiological and environmental demands is a hallmark of astute adaptation (Thayer et al., 2012). The model ultimately suggests a core set of neural structures—the central autonomic network (CAN)—monitors the concordance between the external milieu and internal homeostatic processes to produce motivational drive states and physiological adjustments that prompt adaptation to maintain or recalibrate concordance (Thayer et al., 2012).

The CAN is comprised of several brain regions, including the anterior cingulate cortex (ACC), anterior and posterior insula, ventromedial prefrontal cortex (VMPFC), orbitofrontal cortex (OFC), amygdala, bed nucleus of the stria terminalis, hypothalamus, periaqueductal gray, parabrachial nucleus, nucleus of the solitary tract, nucleus ambiguus, the dorsal motor nucleus of the vagus, noradrenergic locus coeruleus, and rostral and caudal ventrolateral medulla (R. Smith et al., 2017). The CAN is deemed the neurophysiological command centre that governs cognitive, behavioural, and physiological responses and which integrates these responses into regulated emotional states (Appelhans & Luecken, 2006). The primary output of the CAN occurs via preganglionic SNS and PNS neurons that innervate the sinoatrial node of the heart through the stellate ganglia and vagus nerve, which collectively determine HRV (R. Smith et al., 2017). As the CAN receives afferent input from the body and external world, HRV is also reflective of integration between the peripheral and central nervous systems (R. Smith et al., 2017). HRV is therefore thought to provide critical insight into an individual's capacity to function effectively in a complex milieu (Thayer et al., 2012). One core element of this model is the recognition of a fundamental connection between the prefrontal cortex (PFC) and heart via the CAN and vagus nerve (Thayer et al., 2009).

According to the neurovisceral integration model, HRV serves as a marker of self-regulation because it provides a peripheral index of PFC functioning (Thayer et al., 2009). HRV is also associated with neural structures involved in appraising threat and safety at conscious and unconscious levels (Thayer et al., 2012). At rest, and when one's milieu is perceived to be innocuous, the PFC's tonic inhibition of the amygdala maintains a state of calm (Thayer et al., 2012). In response to stressors, however, critical areas of the PFC become hypoactive, and removal of inhibition on the amygdala (i.e., a brain region involved in emotion and detection of salient stimuli) permits an increase in physiological activity to mobilize a response (Thayer et al., 2012). As a result, the central nucleus of the amygdala can be activated and, through a resultant neural cascade, vagal motor neurons are inhibited (Beauchaine & Thayer, 2015), resulting in a phasic decrease in parasympathetic activation and concordant decrease in HRV (Thayer et al., 2012). This suggests cognitive challenges and stressors may decrease HRV via perceptions of threat that activate the amygdala and feedforward to the PFC. Through this network, efficient PFC functioning consequently translates into high tonic HRV and well-regulated phasic HRV, reflective of higher vagal tone (Beauchaine & Thayer, 2015; Thayer et al., 2012).

Owing to associations with the PFC, the seat of executive functions in the brain (Suchy, 2009), high HRV has also been associated with better executive functioning as indicated by better performance across several cognitive tasks such as attention, working memory, and inhibitory control (Beauchaine & Thayer, 2015; Segerstrom & Solberg Nes, 2007; R. Smith et al., 2017). Executive functioning is a broad and multifaceted neuropsychological construct that refers to higher-order, top-down neurocognitive processes that enable individuals to engage in goal-directed and purposeful behaviours, and it is closely linked to the capacity for self-regulatory control (Diamond, 2013; Suchy, 2009).

In accordance, recent meta-analyses have empirically established the capacity of HRV to provide an index of individuals' capacity for self-regulation. Zahn et al. (2016) conducted a meta-analysis of 26 studies ($N = 2317$) and 132 effects to examine the association between resting HRV and participants' self-control[1] in tasks performed in the laboratory and found a small effect ($r = .15$) suggesting higher HRV was associated with better self-control. Similarly, in a meta-analysis of 123 studies ($N = 14{,}347$), Holzman and Bridgett (2017) revealed a small effect ($r = .09$) associating HRV and top-down self-regulation vis-à-vis executive functioning, emotion regulation, and effortful control. Higher HRV therefore offers a robust index indicative of better top-down self-regulation. Consequently, Thayer et al. (2009) have proposed HRV may be critical in determining the integrity of neural networks that support goal-directed behaviour.

As stressors prompt hypoactivation of the PFC and a simultaneous reduction in HRV, it is perhaps unsurprising that low HRV is linked to reduced capacity for self-regulation. Although

[1] Zahn et al. (2016) highlighted that the terms self-regulation and self-control are often used interchangeably. Some researchers distinguish self-regulation as describing automatic regulatory processes, whereas self-control describes the deliberate regulation of behaviours and impulses. Given their focus on links between HRV and tasks involving deliberate behavioural responses, they opted to use the term self-control. The terms self-control and self-regulation are used interchangeably within this document.

some have argued a greater level of vagal withdrawal (i.e., a greater phasic decrease in HRV) in response to a stressor may be adaptive, it appears this may only be so when an individual is faced with a physical stressor or a mental stressor that does not involve executive functioning (Laborde et al., 2017), such as during emotional provocation or expression without a task requiring cognitive effort (Neumann et al., 2004). In response to anger provocation, for example, enhanced vagal withdrawal would facilitate the mobilization of fight-or-flight to either aggress or escape (Porges, 2009). By contrast, when the stressor requires executive functioning, greater vagal withdrawal appears maladaptive (Laborde et al., 2017), such as when required to make a decision under pressure (Laborde et al., 2014). Excessive vagal withdrawal in such scenarios appears to interfere with the capacity to implement the self-regulatory control necessary to facilitate effective cognitive performance (Laborde et al., 2014). In light of the functional connectivity outlined by the neurovisceral integration model and HRV's link to self-regulatory behaviour, it is reasonable to propose HRV may play a role in restrained eaters' disinhibition, which seems to reflect a breakdown of self-regulation and goal-directed restraint of food intake.

1.2.3 *HRV and Restraint Theory*

Taken together, in accordance with the tenets of Porges' (1995) polyvagal theory and Thayer et al.'s (2009) neurovisceral integration model, it is conceivable that HRV, as a proxy for self-regulation, could mediate the relationship between stressful or demanding tasks and disinhibited eating among restrained eaters. Reflecting withdrawal of the PNS's inhibition of HR and efforts to adapt to an environmental stressor, HRV would be expected to decrease upon experiencing a challenging task (Porges, 2003; Porges, 2007b), such as the types of tasks shown to evoke disinhibition. Even a task such as a preload that is not intended to be stressful could be perceived as stressful for restrained eaters given the preload's violation of their dietary rules. In conjunction, this phasic decrement in HRV would theoretically lower their capacity for subsequent self-regulation due to links between HRV and PFC activity (R. Smith et al., 2017; Thayer et al., 2012). For those high on restrained eating, a physiological reduction in the ability to self-regulate could causally evoke the release of their typically rigid control over their intake, particularly when palatable food items are present, thereby undermining restraint.

1.4 The Current Program of Research

To summarize, over 40 years ago, restraint theory expounded that restrained eaters must exert cognitive control to maintain their dietary restraint and are prone to exhibit episodes of overconsumption when this control is disrupted (Herman & Mack, 1975). Over a decade has passed, however, since Lowe and Kral (2006) asserted that an explanation as to *why* restrained eaters exhibit disinhibition remains elusive. However, a clear understanding of the causal mechanism behind this phenomenon has yet to be articulated. Though self-regulation is implicated as a key factor (Johnson et al., 2012; Schaumberg et al., 2016), it remains to be objectively quantified as a mediating factor between individuals' exposure to stress and subsequent consumption when provided ad libitum access to palatable food.

Consequently, the objective of Study One in the current program of research was to delineate when, how, and for whom the tenets of restraint theory may be applicable. Self-regulation was objectively explored via HRV as a feasible causal mechanism that could trigger disinhibition. It was reasoned that isolating a psychophysiological causal factor might lead to novel strategies to attenuate disinhibition, as HRV can be modified via biofeedback (Lehrer, 2013) and other easily-implemented interventions (Petrocchi et al., 2017). In line with this reasoning and anticipated findings from Study One, it was initially proposed that Study Two would examine whether increasing HRV post-stress could attenuate disinhibition. In preparation for this aim, a pilot study was conducted prior to Study One with 59 female undergraduate students to validate a task capable of increasing HRV. The pilot study (McGeown & Davis, 2019) effectively replicated Petrocchi et al.'s (2017) task shown to enhance HRV. However, antithetical results in Study One required a reconfiguration of Study Two. In an attempt to understand the causal sequence that emerged, Study Two explored whether a shift in attentional bias to food was causally implicated in generating stress-induced changes in eating associated with HRV.

Four chapters follow this introductory chapter. Chapter 2 presents the results of Study One examining the role of HRV as a mediator between a laboratory stressor and participants' consumption as moderated by restraint. Thereafter, Chapter 3 delineates the link between Study One and Study Two. Chapter 4 subsequently presents the results of Study Two, exploring a more complex serial mediation model via HRV and attentional bias towards food. The final chapter, Chapter 5, constitutes a general discussion that explores the broader theoretical and practical implications of this program of research, central limitations, and proposed future directions. Throughout this dissertation, HRV is discussed as a potential mediator or causal mechanism, however it is clearly acknowledged at the outset that HRV is understood to serve as a marker of key psychophysiological phenomena (i.e., self-regulatory capacity), rather than acting as a causal agent in its own right.

Chapter 2. Can Heart Rate Variability Predict Disinhibited Eating Among Restrained Eaters?

2.1 Introduction

As detailed in Chapter 1, despite the myriad of experimental manipulations found to prompt restrained eaters' disinhibition, a parsimonious explanation of the mechanism underlying this effect is lacking (Coletta et al., 2009; Lowe & Kral, 2006). The question then arises, what ultimately accounts for disinhibition? Based on findings to date, one of the central mechanisms responsible appears to be the depletion of limited cognitive resources (Hagan et al., 2017), whereby previous acts of self-control lead to a state of "ego depletion" and exacerbate the difficulty of engaging in further self-regulation (Baumeister, 2014; Geisler et al., 2016). To date, self-control has merely been inferred to play a role in restrained eaters' disinhibition based on the supposed requirements of tasks that prompt it. The current study thus sought to examine heart rate variability (HRV), given that it is a viable candidate to objectively index self-regulation (Holzman & Bridgett, 2017; Thayer et al., 2009; Zahn et al., 2016). The theoretical background of the neurovisceral integration model (R. Smith et al., 2017) and Porges' polyvagal theory (1995) as they pertain to HRV was articulated in Chapter 1. Plausible empirical links between restraint theory and the aforementioned theories of HRV are explicated below.

2.1.1 Heart Rate Variability (HRV)

2.1.1.1 *Linking Polyvagal Theory and Restraint Theory*

Though no studies have examined restrained eaters' HRV reactivity in response to the manipulations employed in investigations of disinhibited eating, evidence indicates tasks or stressors similar in their cognitive requirements and parameters decrease HRV. For example, one task shown to instigate disinhibition is the Stroop Colour-Word task (Lattimore & Maxwell, 2004; Wallis & Hetherington, 2004), which was found to significantly decrease HRV in a sample of university students (Brugnera et al., 2018). Other tasks often used to provoke disinhibition include induced failure and speech tasks (e.g., Heatherton et al., 1991). Such tasks resemble the Trier Social Stress Test (TSST; Kirschbaum et al., 1993) and Montreal Imaging Stress Task (MIST; Dedovic et al., 2005). Both the TSST and MIST include social evaluative stress and induced failure, and both the TSST (Shahrestani et al., 2015) and the MIST (Brugnera et al., 2017, 2018; La Marca et al., 2011) significantly reduce HRV. Further, Castaldo et al. (2015) reported in a meta-analysis that a number of acute mental stressors (i.e., Stroop Colour-Word, speech and arithmetic tasks, academic examinations) significantly decrease HRV. Based on these findings, it seems reasonable to posit that, in studies of disinhibition, individuals likely exhibited decreased HRV prior to the taste test that follows in this paradigm. The neurovisceral integration model would predict a corresponding attenuation of self-regulatory capacity that could impact restrained eaters' ability to exert restraint when given palatable food.

2.1.1.2 *Neurovisceral Integration Model and Restraint*

To date, studies have only examined links between restrained eating and tonic HRV with no definitive findings. Meule, Vögele, & Kübler (2012) found restrained eaters had nonsignificantly lower resting HRV than unrestrained eaters, while Geisler et al. (2016) found a nonsignificant positive association between resting HRV and restraint. As resting HRV is thought to reflect a trait-based indicator of HRV (Zahn et al., 2016), other trait characteristics might moderate this association. For example, restrained eaters who report greater perceived self-regulatory success in dieting endorse lower trait impulsiveness (van Koningsbruggen et al., 2013). Accordingly, among those currently dieting, greater perceived dieting success was associated with higher HRV (Meule, Lutz, et al., 2012b). Meule, Freund, et al. (2012) also found binge eating was negatively correlated with resting HRV in those who endorsed higher trait food craving. As low trait impulsivity reflects a greater capacity for self-control (van Koningsbruggen et al., 2013) and self-control is associated with higher HRV (Zahn et al., 2016), this strengthens the notion that HRV could be related to restrained eaters' vulnerability to disinhibition. Apropos episodic disinhibition, however, phasic changes in HRV may have greater predictive power.

Though no published studies have examined whether restrained eaters' disinhibition is mediated by HRV, there is some evidence that HRV could play a role in prompting episodes wherein individuals lose control over eating. In a study of 17 adolescent girls, Ranzenhofer et al. (2016) examined the temporal relationship between HRV and loss-of-control eating using ecological momentary analysis and Holter monitoring of HRV. Within-subjects analyses revealed that participants displayed lower HRV 30 min prior to loss-of-control eating episodes compared to other eating episodes. Though intriguing, this study did not examine restraint status. The study was also limited by its small sample size and inclusion of those who reported at least two loss-of-control episodes in the month prior with a body mass index (BMI) at or above the 85^{th} percentile (Ranzenhofer et al., 2016). Sole inclusion of those with a BMI in the overweight to obese range may be problematic when seeking to generalize these findings to the broader population, as those at a higher BMI tend to exhibit lower HRV to begin with (Chintala et al., 2015). Notwithstanding, this study suggests low HRV may be involved in triggering disinhibited eating. HRV may also be related to binge eating in women with binge eating disorder.

Friederich et al. (2006) found the degree of HRV reactivity exhibited by women with obesity and binge eating disorder during two mental stress tasks (i.e., the Stroop-Colour Word and delayed auditory feedback tasks) was significantly negatively associated with subjective hunger and self-reported binge eating frequency such that greater reduction in HRV was associated with elevated hunger and binge eating frequency. These findings could suggest HRV reactivity to stress may influence the occurrence of binge eating for those prone to engage in such behaviour. A similar pattern may exist among restrained eaters. However, given the correlational nature of Friederich et al.'s (2006) data and the use of self-report to capture binge eating, causal conclusions cannot be made. Inferences are once again also limited by the sample's characteristics, as women with obesity and binge eating disorder may differ from restrained eaters who do not have a clinical eating disorder and vary in BMI status. Given this paucity of studies, the impact of stress-induced changes in HRV on self-regulatory control ought to be explored in restrained eaters more specifically.

To this author's knowledge, only one study has explicitly examined HRV reactivity among restrained eaters in relation to ego depletion and self-regulatory capacity. Geisler et al. (2016) explored how a preceding act of self-control may influence subsequent initiation of effortful self-control, as indexed by HRV, upon exposure to food. Results indicated restrained eaters exhibited higher HRV when presented with food to view and rate on appearance if they had been asked to suppress their emotions while watching a preceding film, though not when they could let their emotions flow freely. Geisler et al. (2016) inferred that exercising self-control and later pursuing the goal of weight control in the food exposure task required the exertion of more effortful self-control, as reflected by enhanced HRV. These conclusions appear to contradict the currently proposed causal pathway whereby ego depletion or stress is expected to lead to *decreased* HRV and disinhibition upon exposure to food. However, a number of methodological considerations set Geisler et al.'s (2016) study apart from the current study.

To begin, an emotional suppression task varies considerably vis-à-vis the level of ego threat posed relative to tasks shown to evoke disinhibited eating in restrained eaters. Ego threat has been identified as a particularly critical element in eliciting disinhibition (Heatherton et al., 1991; Lattimore & Maxwell, 2004; Stroebe et al., 2008) and is conceptualized as a threat to an individual's sense of personal security and integrity, either with respect to their self-concept or sense of control over negative events (Leary et al., 2009). It is unlikely that suppressing emotions in response to an emotion induced via a film clip would be interpreted as a personally-relevant threat. The extent to which the emotion suppression task was experienced as ego depleting or stressful is also questionable. Though the ego depletion condition reported greater mental fatigue, the conditions did not differ in their self-reported affective valence, arousal, or alertness on the Multidimensional Mood Questionnaire (Geisler et al., 2016). It is also noteworthy that in Holzman and Bridgett's (2017) meta-analysis, emotional suppression had an effect size of $r = .00$ with respect to its effect on HRV. This may further call into question whether this task was ego depleting, as it is suspected ego depletion should elicit a stress response that would alter HRV.

Further, Geisler et al. (2016) used a Polar RS800CX heart rate monitor (HRM) to assess HRV. As HRMs tend to overestimate HRV compared to electrocardiogram (ECG; e.g., Nunan et al., 2008; Wallén et al., 2012), inaccurate measurement might have detracted from the ability to accurately ascertain the relationship between HRV and self-control. Geisler et al. (2016) also noted a taste test followed the food exposure, though these results were not reported. Upon contacting the authors, it was discovered restraint status did not interact with the ego depletion condition in predicting consumption (F. Geisler, personal communication February 9, 2018). However, in addition to the questionable experimental manipulation, the food items presented were various flavours of jellybeans. Typical taste tests have used calorie-dense, highly palatable foods such as cookies, M&M's, or potato chips, incorporating foods high in both sugar and fat (Shapiro & Anderson, 2005) that are rated higher in palatability and craving than jellybeans

(Blechert et al., 2019). Geisler et al.'s (2016) study thus does not definitively indicate how a stressful task may evoke restrained eaters' disinhibition via HRV for palatable food items.

Notably, Spitoni et al. (2017) found contrasting findings to Geisler et al. (2016). Though focused on comparing women with and without obesity, the women with obesity had significantly higher restraint. After tasks requiring inhibitory control that would theoretically create a state of ego depletion, women with obesity exhibited significantly greater HRV reduction upon exposure to images of food compared to women without obesity. The women with obesity also demonstrated significantly greater deficits on the inhibitory tasks (Spitoni et al., 2017). As these women exhibited BMIs in the obese weight class according to the International Classification of Diseases (ICD-10; World Health Organization, 2005), the findings may not generalize to the wider population of restrained eaters who exhibit varying levels of BMI. However, given that restrained eating is linked to increased risk for future weight gain and the onset of obesity (Dong et al., 2015), such deficits in inhibitory control and subsequent reactivity to food could be evident prior to substantial weight gain and factor into the onset of obesity.

Evidence of differences in brain functioning among restrained eaters might similarly point towards a role for HRV as a metric of self-regulatory capacity in disinhibited eating. During resting state functional magnetic resonance imaging, Dong et al. (2015) found women with higher restraint in a state of food deprivation exhibited more spontaneous neural activity in the orbitofrontal cortex (OFC) and ventromedial prefrontal cortex (VMPFC), regions associated with expectation and valuation of food rewards, and reduced activity in the bilateral dorsal-lateral prefrontal cortex (DLPFC), a region associated with inhibitory control. Decreased local synchronization in the right DLPFC and increased local synchronization in the right VMPFC mediated the association between women's baseline restrained eating and weight gain at one-year follow-up (Dong et al., 2015). Decreased capacity for self-regulation coupled with increased valuation of food may thus contribute to weight gain in restrained eaters, which might feasibly occur through repeated episodes of disinhibition where the reward value of food wins out over inhibitory control. Wang et al. (2016) similarly found restrained eaters exhibited hyperactivation in the insula and OFC (i.e., reward regions) and hypoactivation in the anterior cingulate cortex (ACC), another area linked to cognitive control, upon exposure to high-energy food images.

The reader may recall from Chapter 1 that the ACC, insula, VMPFC, and OFC belong to the central autonomic network (CAN) and can exhibit feedforward and feedback effects with the heart that influence HRV (Thayer et al., 2012). Hypoactivation in regions associated with cognitive control could be reflected in lower HRV and, consequently, reduced capacity for self-regulatory control when confronted with palatable food. This may be exacerbated by stressful tasks that further attenuate HRV. Coupled with reward-related brain activity (Wang et al., 2016), the risk of disinhibition may be increasingly elevated. Arguably, such findings suggest it may be worthwhile to revisit the process model of ego depletion given its allusion to reward valuation.

2.1.2 The Process Model of Ego Depletion

As noted in Chapter 1, the process model of ego depletion is proposed as an explanatory framework for the occurrence of restrained eaters' disinhibited eating (Geisler et al., 2016). Empirical evidence substantiates the process model of ego depletion outside of its application to restrained eaters. Schmeichel et al. (2010) found individuals who underwent a self-control task reported increased approach motivation and behaviourally demonstrated heightened incentive sensitivity and approach motivation relative to those who were not "ego-depleted." It is feasible that a similar shift in approach motivation may occur in restrained eaters under conditions that lead to disinhibition. As restrained eaters may be more prone to exhibit an enhanced approach motivation or appetitive drive towards food to begin with (Johnson et al., 2012), they may be particularly vulnerable to further increases in approach motivation when their self-regulatory resources are diminished.

Indirect evidence suggests restrained eaters' self-regulatory capacity may interact with their motivational orientation towards food in predicting eating behaviour. In one study, self-reported unsuccessful dieters (i.e., those with lower self-regulatory capacity) exhibited elevated food craving (i.e., a greater appetitive drive for food) compared to successful dieters (Meule, Lutz, et al., 2012a). As noted above, dieters who perceive themselves as unsuccessful also exhibit lower HRV than successful dieters (Meule, Lutz, et al., 2012b), suggesting a feasible link between low HRV, craving or appetitive motivation towards food, and success in maintaining restraint. In yet another study, Meule, Freund, et al. (2012) explored the use of HRV biofeedback to decrease trait food cravings in those who experienced frequent cravings. In the biofeedback condition, 12 20-min biofeedback sessions aimed to increase HRV were conducted over four weeks. Those with high trait food craving who engaged in biofeedback reported significant reductions in trait food cravings and greater control over cravings compared to high food cravers in the control group (Meule, Freund, et al., 2012). Although biofeedback did not alter resting HRV posttraining, it is possible that HRV reactivity patterns may have changed. However, Meule, Freund, et al. (2012) did not examine participants' HRV reactivity. Further, while the researchers only examined self-reported eating behaviour, Meule, Freund, et al.'s (2012) findings broadly suggest appetitive orientation towards food may be related to HRV, whereby higher HRV may reduce cravings. Further studies suggest restrained eaters' neural activity in response to distress is altered in a way that may support approach-related, appetitive behaviour.

Indeed, inducing emotional distress among chronic female dieters increases activity in brain regions associated with reward upon viewing appetizing food cues, suggesting distress may sensitize the brain's reward system to appetitive stimuli among more highly restrained eaters (Wagner et al., 2012). This may provide a mechanism through which restrained eaters' motivational orientation shifts towards gratifying food-related desires. Based on evidence from animal models that stress dampens control of the PFC over behaviour (e.g., Arnsten, 2009), Wagner et al. (2012) proposed distress may disrupt effective self-regulation by reducing top-down control from the PFC. In conjunction with an amplified response to the hedonic value of food, these factors may conspire to provoke self-regulatory collapse (Wagner et al., 2012).

As restrained eaters vary in their vulnerability to disinhibited eating (Johnson et al., 2012; Schaumberg et al., 2016), it is possible differences in their tendency to shift their motivational orientation to food in response to ego depletion may impact their likelihood of disinhibition. Of relevance, Holzman and Bridgett (2017) postulated differences in individuals' behavioural inhibition or approach may interact with top-down self-regulation in the emergence of complex behavioural patterns. Consequently, a secondary aim of this study was to examine whether individuals' motivational orientation towards avoidance or approach interacts with HRV and dietary restraint in predicting disinhibited eating. A viable objective proxy to examine alterations in motivational orientation is a psychophysiological variable known as frontal asymmetry (E. Smith et al., 2017). Assessing motivational orientation objectively offers methodological advantages analogous to those noted for self-regulation in Chapter 1.

2.1.2.1 *Frontal Asymmetry*

A well-established literature indicates that the differential lateralization of frontal cortical activity is associated with opposing motivational propensities (Kelley et al., 2017; E. Smith et al., 2017). Greater relative left frontal activity is characteristic of an approach-motivated tendency associated with heightened responsivity to appetitive stimuli, whereas greater relative right frontal activity is associated with the predominance of withdrawal from or avoidance of aversive stimuli (Kelley et al., 2017; Pizzagalli et al., 2005; E. Smith et al., 2017). This relative balance between left and right frontal activity is referred to as frontal asymmetry. Resting frontal asymmetry is proposed to reflect one's trait motivational response tendency (Kelley et al., 2017). Frontal asymmetry can also capture state-based changes in approach motivation (Harmon-Jones & Gable, 2017). Using electroencephalography (EEG), frontal asymmetry is defined as the difference in alpha activity between the left and right frontal sites (E. Smith et al., 2017).

Observed differences in motivational response tendencies reflected in frontal asymmetry may be linked to an asymmetry of frontal dopamine binding. Greater dopamine binding is documented in left frontal regions (Tomer et al., 2014), which may account for elevated reward responsivity associated with lateralization of activity to the left frontal cortex. Greater left frontal activity during reward anticipation also converges with increased blood oxygenation level-dependent activity in brain regions associated with reward (i.e., the left ACC, medial PFC, and left OFC; Gorka et al., 2015) previously described to play a role in restrained eaters' propensity for future weight gain and responsivity to palatable food images (Dong et al., 2015; Wang et al., 2016). Taken together, in accordance with the process model of ego depletion, the proposed shift in motivational orientation towards gratifying desires following exertion of self-control may manifest in left frontal asymmetry. This conjecture has been substantiated in the literature.

Schmeichel et al. (2016) found participants randomized to a self-control writing condition (i.e., told to write a story without using the letters *a* or *n*) exhibited increased relative left frontal cortical activity while subsequently viewing positive and negative pictures compared to those in the free writing condition who did not exercise self-control. This effect was particularly evident among those with higher scores on the BAS and when viewing positive pictures (Schmeichel et al., 2016). These results corroborate the notion that ego depletion may, in fact, increase approach motivation as evidenced by greater left frontal asymmetry, though not in a food-related context.

Additional evidence indirectly supports the hypothesis that left frontal asymmetry may influence vulnerability to engage in disinhibited eating. Among individuals with obesity, both self-reported disinhibition and appetitive responsivity were associated with greater relative left PFC activation (Ochner et al., 2009). Winter et al. (2016) later found left frontal asymmetry was associated with greater drive for highly palatable foods in those without obesity. Thus, it seems reasonable to speculate that those with high restraint who exhibit greater left frontal asymmetry in response to a stressor, reflecting a proxy for an approach-oriented motivation, may show an enhanced proclivity towards disinhibition. Frontal asymmetry could thus assist in understanding the physiological mechanisms underlying disinhibition and account for heterogeneity in restrained eaters' success, or lack thereof, in maintaining restraint.

2.1.3 The Current Study: Study One

Study One thus sought to answer the following questions: (a) Does HRV mediate the relationship between stress and consumption and does dietary restraint moderate this indirect effect, thereby explaining restrained eaters' disinhibited eating? and, as a secondary aim, (b) Are restrained eaters who exhibit a greater shift in motivational orientation towards an approach bias (i.e., greater left frontal asymmetry) during a stressor more vulnerable to this mediated pattern of disinhibition? The MIST was utilized as the stressor as described in section 2.2.3.2 below. In light of the literature reviewed, the following hypotheses were put forth:

1) Decreased HRV will mediate an association between the MIST stress condition and participants' consumption. This mediation will be moderated by dietary restraint in the pathway between HRV and consumption, such that the link between low HRV and consumption will be stronger among those with higher dietary restraint (Figure 1).

As noted earlier, the MIST significantly decreases HRV (i.e., Brugnera et al., 2017, 2018; La Marca et al., 2011). Given that restrained eaters are striving to strictly regulate their intake with respect to the type or amount of food, they should be more vulnerable to the impact of lower self-regulatory capacity when provided ad libitum access to palatable foods. In line with the secondary focus of this study, it was further reasoned restrained eaters who exhibit a greater motivational shift towards an approach bias may be especially vulnerable to engaging in disinhibited eating. It was therefore hypothesized that:

2) The indirect effect of stress on consumption as mediated by decreased HRV will be moderated by an interaction between dietary restraint and frontal asymmetry, such that the association between low HRV and consumption will be stronger in those who report higher restraint and exhibit greater left frontal asymmetry during the MIST (Figure 2).

2.2 Method

2.2.1 Participants

A total of 103 female participants were recruited from Lakehead University's Department of Psychology undergraduate participant pool at the Thunder Bay campus through the Sona Experiment Manager system. Participants ranged in age from 15[2] to 58 years (M = 20.78, SD = 6.08). Most participants self-identified as Caucasian (73.8%). The remainder reported Aboriginal (4.9%), South Asian (3.9%), African-Canadian (6.8%), Hispanic (1.9%), East Asian (2.9%),

[2] Researchers only became aware of this participant's age at the end of the study when reviewing her demographics questionnaire. The participant had immigrated from Africa and was enrolled as a student at the university.

Middle Eastern (1.0%), and "Other" (3.9%) ethnicities. "Other" ethnicities reported included South East Asian and Indian. Participants' BMIs ranged from 13.32 to 40.53 kg/m^2 (M = 24.80; SD = 4.87). All participants had normal or corrected-to-normal vision. As compensation, participants were awarded two bonus points to count towards their final grade in an eligible undergraduate course and entered into a draw to win one of five $100 pre-paid Visa gift cards.

A priori power analyses are difficult to conduct for mediation and moderated mediation models, as there is no agreed upon way to quantify the magnitude of the indirect effect (Hayes, 2018a). To determine an appropriate sample size, relevant resources were thus consulted for guidance. Quintana (2017) conducted an effect size distribution analysis of 297 HRV studies to guide the planning of suitably powered studies. To achieve a power of 0.8, a sample size of 61 was deemed necessary to detect a medium effect. Based on the small-to-medium effect (d = 0.43) of Brugnera et al. (2017) for the MIST on HRV, it was determined that a sample size larger than 61 was warranted. Further, Preacher et al. (2007) conducted a simulation study to guide sample size selection for certain mediation and moderated mediation models based on specified regression coefficients representing different sized effects, assuming equivalent model paths. As regression is equivalent to analysis of variance (ANOVA) with two groups, the d of .43 from Brugnera et al.'s (2007) study was used to gauge the coefficient. Using bootstrapping with a coefficient of 0.39, 100 participants would yield power of 0.963 in this model. A sample of 100 was thus deemed a reasonable aim given the inclusion of covariates, which would attenuate power, and normal loss of data due to artifacts in HRV recordings and potential technological recording errors. Bootstrapping also provides high statistical power (Preacher & Hayes, 2008).

Participants were required to be (a) non-smokers, (b) not taking any cold, antidepressant, or hypertensive medication, and (c) right-handed, as smoking status and such medications can influence HRV (Laborde et al., 2017), and handedness can influence cortical lateralization (Kelly et al., 2015). They were also instructed to refrain from exercising, drinking caffeine, or eating 2 hr prior to their laboratory session and to abstain from alcohol 24 hr prior, as these factors influence HRV (Sarlon et al., 2018). Further, only females were included in the study. The central reason for this was that the accessible population was predominantly female, and there are notable differences in the average levels of restraint across males and females (Polivy et al., 2020). Females primarily constitute the majority of restrained eaters (de Witt Huberts et al., 2013), and males tend to exhibit lower dietary restraint (Polivy et al., 2020). There was concern that, given the small number of potential males, an uneven distribution of males would likely arise in the stress and control conditions, thereby creating potential differences in restraint across conditions. Such differences would have complicated the ability to differentiate the cause of variance in consumption across conditions. Further, given the small number of males, it would not have been possible to conduct subgroup analyses across gender, thereby minimizing the utility of their inclusion in this study.

The number of participants excluded differed across hypotheses one and two to retain the greatest power in analyses. For hypothesis one, six participants were excluded. One participant was excluded because she divulged prior to the taste test that she had an allergy to dairy and thus was not be able to consume the food items. Two participants were removed because an ECG electrode fell off during a key recording, rendering the signal unusable. Three additional participants were removed for answering all of the attentional assessment questions following the baseline video incorrectly, as it was concluded these participants had not adequately attended to the baseline stimuli, and the quality of their baseline recording was therefore questionable. All participants excluded for hypothesis one were also excluded in analyses of hypothesis two, in addition to the exclusion of five participants for measures pertinent to EEG.

EEG data were examined for outliers, defined as a *z* score of ± 3.29 (Field, 2013). Based on raw EEG spectral power, one participant was removed for excessive signal distortion shown by extreme μV^2 values. As is customary prior to computing frontal asymmetry (E. Smith et al., 2017), raw spectral power at F3 and F4 was log transformed. One participant was removed as an extreme outlier on log transformed F3 and F4 values. Three participants were then excluded due to extreme outlier values on frontal asymmetry during the MIST. One participant was excluded due to ambidextrous handedness (Kelly et al., 2015). The final sample used in statistical analyses thus consisted of 97 participants for hypothesis one and 92 participants for hypothesis two.

2.2.2 Materials

2.2.2.1 *Demographics Questionnaire*

Participants were asked to complete a demographics questionnaire to assess characteristics such as age, marital status, prescription medication usage, and ethnicity (Appendix M). The questionnaire also included questions pertaining to food restrictions (i.e., veganism, vegetarianism, food intolerances/allergies), and menstrual cycle, as described below.

2.2.2.1.2 Menstrual Cycle Phase. To provide an approximate control for menstrual cycle phase, participants were asked to report the number of days since the onset of their last menses in accordance with methodology used by Dong et al. (2015) and Wang et al. (2016). Allen et al. (2016) note this method is appropriate when budget or logistical constraints are present that prevent the use of other recommended methodologies for identifying menstrual phase, such as sex hormone measurement via blood or saliva. Participants were also asked to indicate whether they were currently taking oral contraceptives.

Questions related to menstrual phase and oral contraceptive use were included given links between fluctuations in ovarian hormones and variability in binge eating (Klump et al., 2008), changes in HRV across the menstrual cycle (Tenan et al., 2014), potential differences in physiological responses to stress associated with oral contraceptive use (Laborde et al., 2017), and associations between resting state alpha frequency and menstrual cycle phase and oral contraceptive use (Brötzner et al., 2014). Despite empirical justification for including these variables, neither days since the onset of last menses nor oral contraceptive use were significantly correlated with HRV metrics, frontal asymmetry, or food intake. As such, these variables were not included as covariates in the models analyzed.

2.2.2.2 *Edinburgh Handedness Inventory – Short Form*

The Edinburgh Handedness Inventory – Short Form (EHI-SF; Veale, 2014; Appendix N) is a 4-item questionnaire that assesses handedness, the preference to use one hand with greater frequency to perform daily activities or use common objects. The measure results in laterality quotients ranging from -100 (left-handed) to 100 (right-handed). Participants' self-reported handedness ranged from 0.00 to 100.00 with a mean of 90.20 (SD = 16.84), indicating the sample was predominantly right-handed. Those whose laterality quotient fell between -40 and 40 were deemed ambidextrous (Kelly et al., 2015) and excluded from analyses of hypotheses two.

2.2.2.3 *Quick Inventory of Depressive Symptomatology – Self-Report*

The Quick Inventory of Depressive Symptomatology – Self-report (QIDS-SR_{16}; Rush et al., 2003; Appendix O) is a 16-item self-report questionnaire designed to assess depressive symptoms across nine symptom domains (e.g., sleep, appetite, concentration, etc.; Rush et al., 2003). Participants respond to items based on symptoms present during the prior seven days on a scale ranging from 0, reflecting no symptoms, to 3, reflecting higher depressive symptoms in that domain. Response options have descriptive anchors appropriate to each domain. Total scores can range from 0 to 27. In the current study, the QIDS-SR_{16} demonstrated excellent internal consistency (Cronbach's $\alpha = .91$). The QIDS-SR_{16} was administered given associations between depressive symptoms and HRV (Laborde et al., 2017). However, as scores were not significantly correlated with any HRV metric, it was not included as a covariate.

2.2.2.4 ***Height and Weight Measures***

Participants' height and weight was measured just prior to leaving the laboratory during the study protocol. Weight was measured using a Brecknell (LPS-400) digital scale and recorded in pounds to the nearest tenth of a decimal. Height was measured using a measuring tape affixed to the wall and recorded to the nearest 0.5 cm. To compute participants' BMI, the following formula was utilized: BMI = weight (lb.)/height [in.] × height [in.]) x 703.

2.2.2.5 ***Restrained Eating***

To assess restraint, five dietary restraint scales were administered: the Three-Factor Eating Questionnaire – Restraint scale (TFEQ-R; Stunkard & Messick, 1985), Dutch Eating Behaviour Questionnaire – Restrained Eating Scale (DEBQ-R; van Strien et al., 1986), Revised Restraint Scale (RS; Herman & Polivy, 1975), Eating Disorder Examination-Questionnaire – Restraint subscale (EDE-Q-R; Fairburn & Bèglin, 1994), and Eating Disorder Inventory-3 – Drive for Thinness Scale (EDI-3-DT; Garner, 2004). As noted in Chapter 1, factor analyses suggest items across these measures reflect three latent restraint factors: (a) Calorie Counting, (b) Preoccupation with Dieting; and (c) Weight-Focused Restraint (Hagan et al., 2017). Analyses were run separately with each factor to represent restraint (see Table 1 for items that constitute each factor). Items comprising each factor were summed as per Hagan et al. (2017). Calorie Counting showed good internal consistency (Cronbach's $\alpha = .81$) and both Preoccupation with

Dieting and Weight-Focused Restraint had excellent internal consistency (Cronbach's α = .91 and α = .93, respectively). Analyses were also conducted with the conventional scales in turn.

2.2.2.5.1 Three-Factor Eating Questionnaire (TFEQ). The TFEQ is a 51-item questionnaire comprised of three scales: Restraint, Hunger, and Disinhibition (Stunkard & Messick, 1985; Appendix H). The 21-item[3] Restraint scale (TFEQ-R) was administered in the current study, which measures cognitive restraint (e.g., "I consciously hold back at meals in order not to gain weight"). Items in Part I are responded to as true or false, and the response indicative of the factor assessed receives one point. Items in Part II are responded to on a 4-point or 5-point Likert-type scale and scores are determined by splitting responses at the midpoint. Depending on the wording, scores above or below the middle are given zero and the rest receive one point (Stunkard & Messick, 1985). Scores are derived by summing all items on the scale. The TFEQ-R demonstrated excellent internal consistency (Cronbach's α = .92) in the preliminary validation sample (Stunkard & Messick, 1985) as well as in a subsequent sample of undergraduate students (Cronbach's α = .90; Allison et al., 1992). Among undergraduates, the TFEQ-R displays high test-retest reliability (r = .91) over a two-week interval (Allison et al., 1992). In the current study, the TFEQ-R showed good internal consistency (Cronbach's α = .81).

2.2.2.5.2 Dutch Eating Behaviour Questionnaire (DEBQ). The DEBQ is a 33-item questionnaire with three subscales to assess Restrained, Emotional, and External Eating (van Strien et al., 1986). Only the 10-item Restrained Eating subscale was administered in this study (Appendix I). The DEBQ-R strives to identify restrained eaters who are consciously attempting

[3] Unfortunately, due to human error transposing items into SurveyMonkey™, one item (item 35; "I pay a great deal of attention to changes in my figure") was inadvertently left out. This item is responded to using the true/false response; thus, its absence may have led some participants to score one point lower than they otherwise would have if the item would have been true for them. This error also impacted computation of Calorie Counting, as item 35 loads onto this factor. This error may once again have lowered participants' scores on this factor by one point.

to restrict their intake (e.g., "Do you try to eat less at mealtimes than you would like to eat?"). Items are responded to on a 5-point Likert-type scale, ranging from 1 (*never*) to 5 (*very often*). Scores are obtained by dividing the sum of the items by the number of items on the subscale. Preliminary validation revealed high internal consistency of the DEBQ-R among women with obesity (Cronbach's α = .93) and without obesity (Cronbach's α = .95; van Strien et al., 1986). Allison et al. (1992) also reported high test-retest reliability (r = .92) over two weeks and excellent internal consistency (Cronbach's α = .95) in undergraduate students. In the current sample, the DEBQ-R exhibited excellent internal consistency (Cronbach's α = .91).

2.2.2.5.3 Revised Restraint Scale. The Restraint Scale was originally devised by Herman and Mack (1975) and revised by Herman and Polivy (1975) to form the 11-item Revised Restraint Scale (RS; Appendix J)[4]. The RS was the first measure designed to operationalize the construct of dietary restraint. The RS assesses the degree of self-imposed restriction of food and fluctuations in weight via two subscales: Concern with Dieting (i.e., "How often are you dieting?") and Weight Fluctuations ("What is your maximum weight gain within a week?"). In the preliminary validation sample, the RS displayed acceptable internal consistency (Cronbach's α = .75). In the current study, the entire scale comprising both subscales was utilized, as each subscale demonstrates questionable internal consistency on its own (Herman & Polivy, 1975). Allison et al. (1992) indicated that the RS exhibited high test-retest reliability (r = .95) and good internal consistency (Cronbach's α = .82) in an undergraduate student sample. In the current study, the RS demonstrated adequate reliability (Cronbach's α = .69).

[4] It was discovered following data collection that the RS used in this study differed slightly from that used by Hagan et al. (2017), as the version they employed differed from that cited from Herman & Polivy (1975). The effect of this was that the question "How often are you dieting?" was missing the response option "Never," scored 0. This may have had the effect of increasing participants' scores by 1 point on the RS if they would have otherwise endorsed "Never."

2.2.2.5.4 Eating Disorder Examination-Questionnaire (EDE-Q). The EDE-Q is a 36-item self-report designed to assess the frequency of key behavioural features and the severity of specific psychopathological features of eating disorders (Fairburn & Bèglin, 2008). Only the 5-item Restraint subscale (i.e., EDE-Q-R) was included in the current study (Appendix K). The EDE-Q-R aims to measure attempts to restrict food intake for the purpose of influencing one's body weight or shape (e.g., "Have you been deliberately *trying* to limit the amount of food you eat to influence your shape or weight [whether or not you have succeeded]?"). Items are responded to with respect to the past 28 days. Responses are provided on a 7-point Likert-type scale from 0 (*No days*) to 6 (*Every day*). Subscale scores are obtained by summing the items and dividing by the number of items on the subscale (Fairburn & Bèglin, 1994). The EDE-Q-R demonstrates acceptable to good internal consistency across samples (Berg et al., 2012). Good test-retest reliability has also been shown over 1 to 14 days (r = .77–.81) in two samples, including a community sample of 139 female undergraduate students and 86 men and women seeking treatment for binge eating disorder (Berg et al., 2012), suggesting scores tend to be stable over time. In the current study, the EDE-Q-R had good reliability (Cronbach's α = .85).

2.2.2.5.5 Eating Disorder Inventory-3 (EDI-3). The EDI-3 is a 91-item self-report questionnaire designed to assess eating disorder symptomatology, severity, and risk in addition to general psychopathology (Garner, 2004). Only the 7-item Drive for Thinness (EDI-3-DT) scale was used in this study (Appendix L), which assesses desire to be thinner, concern with dieting, preoccupation with weight, and fear of weight gain (e.g., "If I gain a pound, I worry that I will keep gaining"). Items are responded to on a 6-point Likert-type scale to indicate whether the statement applies "*always*" to "*never*" (Garner et al., 2004). Each item is scored from 0 to 4. The response indicating the highest drive for thinness receives a score of 4; adjacent responses receive descending scores of 3, 2, and 1; and the three choices following receive 0. Scores range from 0 to 28. In the initial development sample, the original DT scale had good internal consistency (Cronbach's $\alpha = .85$; Garner et al., 1983). A validation study of the EDI-3 indicated the DT scale exhibited good internal consistency (Cronbach's $\alpha = .86$) in patients with eating disorders and excellent internal consistency (Cronbach's $\alpha = .91$) in non-clinical controls (Clausen et al., 2011). In this study, the internal consistency was excellent (Cronbach's $\alpha = .91$).

2.2.2.6 *Grand Hunger Scales*

As hunger may influence the amount of food participants consume, they were required to rate their hunger by filling in the Grand Hunger Scales (Grand, 1968; Appendix F). The Grand Hunger Scales assess four indices of hunger: the number of hours since last eating to the nearest 15 min, subjective hunger on a 7-point Likert-type scale from 1 (*not hungry at all*) to 7 (*extremely hungry*), the amount of their favourite food they would be able to consume on a 6-point Likert-type scale from 1 (*none at all*) to 6 (*as much as I could get*), and an estimate of the time until their next expected meal to the nearest 15 min (Grand, 1968). A composite score for the Grand Hunger scales is not able to be derived given the discrepant weighting of each numeric index. As such, Cronbach's alpha was not able to be computed for this measure.

Each item was analyzed for its relation to consumption. As none of the items exhibited a significant association with participants' consumption, they were not included as covariates. Additional questions were affixed to assess thirst, fatigue, and discomfort, each measured on a 7-point Likert-type scale from 1 (*none at all* or *not thirsty/tired at all*) to 7 (*extreme discomfort* or *extremely thirsty/tired*).

2.2.2.7 *Stress Rating Questionnaire*

To verify that the MIST effectively induced stress, the Stress Rating Questionnaire (SRQ; Edwards et al., 2006; Appendix E) was administered at baseline and after the MIST. The SRQ is a 5-item self-report questionnaire designed to assess changes in subjectively-experienced stress, and it is sensitive to changes in state anxiety and stress induced via laboratory stressors (Edwards et al., 2006; Edwards et al., 2015). The SRQ examines stress on five bipolar dimensions: Calm to Nervous, Fearless to Fearful, Relaxed to Anxious, Unconcerned to Worried, and Comfortable to Tense. Each dimension is rated on a 7-point scale. Total scores are computed by summing all items. Scores range from 5 to 35. The SRQ has been employed in prior studies using the MIST (Brugnera et al., 2017, 2018). Brugnera et al. (2017) reported good internal consistency at baseline (Cronbach's $\alpha = .87$) and in the control ($\alpha = .89$) and stress ($\alpha = .88$) conditions. In the current study, the SRQ exhibited acceptable internal consistency at baseline (Cronbach's $\alpha = .72$) and in the control (Cronbach's $\alpha = .88$) and stress (Cronbach's $\alpha = .82$) conditions post-MIST.

2.2.3 Experimental Tasks

2.2.3.1 ***Taste Test***

In the taste test, participants were provided four food items. Though consideration was given to presenting both sweet and savoury foods, Cardi et al. (2015) revealed participants consume more food in response to negative mood inductions when either sweet or savoury foods are presented, rather than both in tandem. Studies presenting both types of foods also show individuals are more likely to consume sweet foods after a stressor (e.g., Boyce & Kuijer, 2014; Monro & Huon, 2006). The current study therefore served only sweet foods. Participants were presented with the following items: M&M's® (4.92 kcal/g), small milk chocolate pieces coated in a crunchy candy shell; Nabisco's Mini Chips Ahoy! (5.00 kcal/g), crunchy, bite-sized chocolate chip cookies; milk chocolate covered pretzels (4.70 kcal/g); and caramel popcorn (3.60

kcal/g). Allergen information specified by the manufacturer was shown prior to the taste test.

The bowls of food were pre-weighed prior to presentation using a Denver Instrument Summit Series S-2002 laboratory scale. All foods were presented in identical clear glass bowls filled roughly to the same point (i.e., two-thirds). The quantity of each food required to fill the bowl to this point was standardized prior to study commencement. Any uneaten food at the end of the taste test was discretely weighed in the back room of the laboratory to quantify how much the participant ate by subtracting the remaining amount from that served. The total amount of food consumed was computed by summing the quantity of each food eaten in g. To validate the guise that the taste test sought to examine taste perception, participants filled out forms rating each food on a number of dimensions, such as sweetness, crunchiness, liking, etc. (Appendix G). Before leaving, participants were offered the opportunity to take home the remaining food in small plastic zipper bags to minimize waste. Otherwise, uneaten portions were disposed of.

2.2.3.2 *Montreal Imaging Stress Task (MIST)*

The MIST is a computerized mental arithmetic protocol designed to induce psychosocial stress in the laboratory (Dedovic et al., 2005). The MIST was presented by Inquisit™ (Version 5.0) software. The MIST incorporates five levels of difficulty for the arithmetic items which vary based on the number of integers and operands involved. In the highest difficulty level, items include four integers and both multiplication and division. For each item, the solution is an integer between 0 and 9. Participants respond by highlighting the integer on a rotary dial onscreen by pressing the left or right mouse buttons. Pressing the left mouse button moves the highlighted number counter-clockwise, pressing the right mouse button moves it clockwise, and the middle mouse button submits the response (Dedovic et al., 2005).

The task begins with a 5 min training phase. In the stress condition, the task is then set to a time limit 10% less than the average response time during training. Response times and accuracy are continuously monitored. If three consecutive items are answered correctly, the time limit is reduced to 10% less than the average for those three; if three are answered incorrectly, the time limit is increased by 10%. This induces a high failure rate and enforces about 20-45% accuracy (Dedovic et al., 2005). A timer onscreen shows the seconds remaining and feedback is presented for each item (i.e., “Correct,” “Incorrect,” “Timeout”). A performance bar is also displayed with two indicators (see Figure 3): one represents participants’ performance (i.e., in the red zone) and the other reflects the supposed average of all participants at 80-90% (i.e., in the green zone). At the end of each block, a page appears that says “Please wait.” At this time, the researcher heightens social-evaluative stress via standardized negative feedback phrases.

In the control condition, arithmetic items are presented at the same levels of difficulty and item-level feedback is still provided. However, there is no time limit per item or performance bar comparing them to others. Under these conditions, the task elicits an accuracy rate of about 80-90% (Dedovic et al., 2005). Similar to the stress condition, a page appears that says “Please wait” between each block. During these breaks, the researcher stated a standardized neutral phrase and reminded participants their performance was not being evaluated. For the cover story, participants were told that the main factor of interest was their cardiac activity while performing mental arithmetic and its relation to their working memory.

As the stress condition may have threatened participants’ sense of numeracy ability, a second round of the MIST was presented after the experimental manipulation and taste test to restore self-efficacy in basic arithmetic before leaving the laboratory. In the stress condition, the second round was similar to the control condition, as the time limit did not vary as a function of their performance. This enabled them to achieve an accuracy level around 80-90%. To restore a sense of performing at the level of peers, the performance bar remained onscreen. The control condition simply engaged in a second round of the original task.

Of critical importance, the MIST was chosen as the stress task because it appears to be the only stress task delineated in the literature with a control condition validated to elicit less physiological stress than the stress condition as indexed via HRV. Brugnera et al. (2017) reported a significant difference in HRV between the stress and control conditions with a small-to-medium effect size $d = .43$. La Marca et al. (2011) similarly found a significant difference with a large effect size ($\eta_p^2 = 0.25$). The MIST thus enabled a powerful and well-controlled stress manipulation.

2.2.3.3 *Electroencephalography (EEG) Recording*

EEG signals were recorded using a 24-channel Waveguard EEG cap from Advanced Neuro Technology (ANT; Enschede, Netherlands) with electrodes at scalp positions F3, F4, C3, Cz, C4, O1, O2, M1, and M2, in accordance with the International Electrode Placement System. Signals were filtered through a 72-channel amplifier (ANT; Enschede, Netherlands) into a computer with Advanced Source Analysis (ASA) 4.7 Experiment Manager (Version 9.2) software. Cortical EEG activity was sampled continuously at a frequency of 1024 Hz. Two electrodes were placed above and below the right eye to record vertical electrooculogram (VEOG) activity to assess eye blinks and optical artifacts. Offline processing was conducted using ASA (Version 4.8.0) software to prepare the signals for analyses. EEG data were first re-referenced to the average of the mastoid electrodes (i.e., M1 and M2). Artifacts exceeding ± 100 μV in amplitude and coinciding with eye blinks from the VEOG were then detected. Additional artifacts were identified via visual inspection. Epochs encompassing artifacts were excluded.

EEG data were high-pass filtered at 24 Hz, with a low cut-off frequency of 0.49 Hz and a high cut-off frequency of 100 Hz. Data were segmented into epochs of 1 s duration, with an interval of 0.5 s between epochs and 50% overlap. To extract power spectral densities in the 8 – 12 Hz alpha frequency band, a Fast Fourier Transform (FFT) was performed at 0.5 Hz intervals using a Hanning window. Resulting EEG spectral data were manually transferred into SPSS v.25.

2.2.3.4 *Electrocardiogram (ECG) Recording*

A three-lead ECG configuration was utilized to record individuals' cardiac activity with snap on Ag-AgCl electrodes placed according to lead II placement. ECG signals were filtered through a 72-channel amplifier (ANT; Enschede, Netherlands) into a computer equipped with ASA 4.7 Experiment Manager software (Version 9.2). ECG was sampled continuously at a frequency of 1024 Hz. Raw ECG data underwent preliminary offline processing and inspection via ASA. ECG data were high-pass filtered at 24 Hz, with a low cut-off frequency of 1 Hz and a high cut-off frequency of 100 Hz. ECG signals were subsequently imported into Kubios software (Version 3.2; Tarvainen et al., 2019) to derive HRV metrics.

Laborde et al. (2017) recommend that to avoid bias, researchers ought to perform analyses with one metric reflecting cardiac vagal tone and compare it to a comparable metric to examine whether results are echoed across similar variables. Both the root mean square of successive R-R differences (RMSSD) and high frequency HRV (HF-HRV) were thus computed to reflect time-domain and frequency-domain indices, respectively, which typically correlate highly (Thayer et al., 2012). However, as described in section 2.3.5 below, as HF-HRV did not show a significant change from baseline to the MIST in the stress condition, HF-HRV was not used to analyze the hypotheses. Instead, analyses were additionally run with Kubios' PNS index, as described below. As the PNS index provides a robust and reliable estimate of vagal activity

(Tarvainen et al., 2019), this allowed for cross-verification of the findings with an additional HRV metric.

2.2.4 Procedure

The procedure was approved by Lakehead University's Research Ethics Board. Female participants were invited to sign up for the study via Lakehead University's Sona Experiment Manager system (Appendix A). Figure 4 displays a timeline of the study's procedure. Upon arrival, participants filled out an eligibility checklist to verify that the preparatory criteria specified in section 2.2.1 were met. Participants then read an information letter (Appendix B) outlining what their participation would entail. If they agreed to participate, participants signed their informed consent (Appendix C). Participants were not informed of the true purpose of the study at the time of their participation. Rather, they were told the study intended to examine the relationship between heart and brain activity and various sensory and cognitive tasks.

Once consent was obtained and the participant's questions were addressed, they were fit with an appropriately sized EEG cap. ElectroGel was applied to the scalp to attain impedance levels below 10 kΩ prior to recording. Two self-adhesive bipolar electrodes were applied for VEOG. Participants were asked to self-apply three Ag-AgCl self-adhesive electrodes for the three-lead ECG configuration based on the diagram provided (Appendix D). Participants were led through the procedure via a SurveyMonkey™ link containing task prompts and required questionnaires displayed on a Toshiba 55-inch diagonal 1080p LED television located 2 m in front of the participant. After briefing participants on the procedure, the researcher retreated to a back room in the laboratory for most of the study to control task presentation and data recording.

Once connected, a 5-min baseline ECG and EEG recording was taken. As per the recommended gold standard for ECG baselines (Laborde et al., 2017), participants were asked to sit with their knees at a 90° angle with both feet flat on the floor and hands on their thighs while remaining still and breathing spontaneously. Participants were instructed to watch a neutral video clip of aquatic life from *Coral Sea Dreaming* (© 1992 Plankton Productions) which was edited in Movie Studio Platinum (Version 12.0) to insert symbols periodically throughout in an area of the visual space. Following the video, participants were asked three questions to indicate what symbol appeared, how many times it was seen, and where it appeared on the screen to ensure they attended to the screen for the video's full duration. A neutral video with an attentional assessment was selected to approximate the visual stimulation and allocation of attention towards the television required by the MIST. This particular video (i.e., *Coral Sea Dreaming* [© 1992 Plankton Productions]) also facilitates a more optimal resting baseline of cardiovascular activity compared to sitting quietly (Piferi et al., 2000). Facilitating a relaxed state can decrease variability in participants' experience of the resting period, thereby attenuating differences that can dilute evidence of task-responsive cardiovascular activity (Piferi et al., 2000).

Participants proceeded to complete the SRQ to indicate baseline stress (Appendix E). Affixed to this scale was a single item to discern their self-perceived mathematics ability (i.e., "I am confident in my ability in mathematics") on a visual analogue scale from 0 (*not at all*) to 100 (*extremely*), as it was reasoned this may impact reactivity to the MIST. Participants were then instructed the first task (i.e., the MIST) would begin. Prior to entering the laboratory, participants were assigned to the stress or control condition by alternating odd and even numbers. The MIST was presented as described in section 2.2.3.2 during which ECG and EEG were recorded. Thereafter, participants filled out the SRQ again and proceeded to the supposed sensory task.

At this time, the researcher emerged from the back room and told the participant that the sensory task they would be allocated to would be selected from a hat to allow randomization. All participants were instructed to pick a slip of paper from the hat; however, all read "taste." This "randomization" was done to reduce the likelihood that participants discerned the experiment was examining their consumption, as participants may alter their eating if they feel their intake is under scrutiny (Herman et al., 2003; Robinson et al., 2015). The taste test was feigned to examine the association between taste perception and cardiac and brain activity. Participants rated their hunger on the Grand Hunger scales in addition to their thirst, fatigue, and discomfort (Appendix F) prior to the taste test under the guise that these variables could affect heart activity and taste perception. These items were answered on a paper questionnaire to substantiate the cover story that the task was randomly chosen and thus was not pre-set in SurveyMonkey™.

The researcher retreated to the back room while this questionnaire was answered to supposedly set up the food. Once signalled that the participant completed the questionnaire, the researcher presented the food described in section 2.2.3.1 on tray. The food items were presented in the same order for all participants. Participants were told they would have 10 min to complete the taste test, as is customary in this paradigm (Robinson et al., 2017). They were informed they had to taste each food sequentially to rate its taste dimensions and how much they liked the food (Appendix G), but that they could eat as much as they desired with the remaining time. A timer appeared onscreen to inform participants how much time remained to complete this task.

As participants' self-efficacy in arithmetic may have been compromised in the stress condition, steps were taken to remedy ethical concerns. Following the taste test, the researcher emerged to apologetically inform those in the stress condition that they started an old draft of the task during the first round in which the timing was faulty. The researcher explicitly noted this was likely the cause of their initial trouble. Participants were told they would complete the task a second time to ensure an accurate assessment of working memory and heart activity. This placed the onus of their poor performance on the researcher's supposed error and enabled them to achieve the typical level of success among those in the control condition. Those in the control condition were told they would perform a second round to assess the reliability of the first round.

Upon completion of the second round of the MIST, the researcher emerged to remove the EEG cap, as well as VEOG and ECG electrodes. The researcher then left the room to clean the EEG cap while the participant completed the remaining questionnaires, including the restraint scales (Appendices H-L), as completion of such measures is typically done after the taste test in this paradigm (Robinson et al., 2017). Participants also completed the SRQ one final time, the demographics questionnaire (Appendix M), EHI – SF (Appendix N), and QIDS-SR_{16} (Appendix O). Once participants were done, they signaled the researcher to enter the room. The researcher then measured participants' weight and height and thanked and dismissed them. The total time to complete the laboratory session was approximately 1 hr 30 min. The study's true purpose and deception were not revealed at the conclusion of each session. Given the small size of the university, this was important to ensure participants did not discuss the study with others in advance of their participation. Once the final participant participated, a debriefing email (Appendix P) was sent. No participants asked for their data to be removed upon this revelation.

2.3 Results

2.3.1 Data Preparation

Data from SurveyMonkey™ and paper-based questionnaires were transferred into SPSS v.25. All data were examined for missing values in SPSS. Missing values were replaced with prorated scores based on individuals' mean score on the scale or subscale in question (Field, 2013). Though the treatment of missing values is an area of controversy among statisticians, it has been suggested that proration may be reasonable when: (1) a high proportion of the items, never fewer than half, are used to form the scale score; (2) the item-total correlations are similar; and (3) the scale exhibits high internal consistency (Mazza et al., 2015).

2.3.1.1 *EEG Data*

To calculate frontal asymmetry scores, alpha power at the left (F3) and right (F4) electrode sites during the baseline and MIST recording blocks first underwent a natural log transformation, in keeping with conventions (E. Smith et al., 2017). As previously noted, one participant was found to be an extreme outlier on the basis of their log transformed F3 and F4 values and was thus excluded. A difference score was subsequently calculated to summarize the relative activity across the left and right frontal cortex (i.e., F4*ln* – F3*ln*) for the baseline and MIST blocks. As alpha power is inversely associated with cortical activity (i.e., greater power equates to less cortical activity, while lower power equates to more activity), higher asymmetry scores indicate greater left-hemispheric activity whereas negative scores reflect greater right-hemispheric activity (Harmon-Jones & Gable, 2009). Frontal asymmetry scores were examined for outliers, defined as cases with a z score of ± 3.29 (Field, 2013). Three outliers were identified on frontal asymmetry during the MIST and were excluded, as it was evident that their extreme values were due to recording errors that caused excessive distortion in the EEG signals.

2.3.1.2 *ECG Data*

Cardiovascular activity recorded via ECG was processed using Kubios HRV software (Version 3.2; Tarvainen et al., 2019). Prior to analyses, artifact correction was performed in a signal pre-processing phase. Kubios enables automatic filtering to detect R-R intervals that differ in an abnormal manner from the mean R-R interval (Laborde et al., 2017; Tarvainen et al., 2019). Artifact correction can then be modified manually via visual inspection. Manual review is recommended as artifacts detected via automatic procedures may correspond to true heartbeats and their deletion can cause a significant loss of information vis-à-vis variability in the signal (Laborde et al., 2017). Artifact correction seeks to eliminate abnormal beats that are not generated by sinoatrial node depolarizations (Laborde et al., 2017). Artifacts judged to reflect true heartbeats were not corrected. Thereafter, RMSSD and HF-HRV were computed by Kubios.

As noted in section 2.2.3.4, the PNS index was also computed. Version 3.2 of Kubios computes the PNS index from the mean R-R interval, RMSSD, and the Poincaré plot index SD1 in normalized units (n.u.; Tarvainen et al., 2019). Parameter values are then compared to normal values reported by Nunan et al. (2010) based on normative HRV values for short-term measures obtained within healthy individuals. Both RMSSD and mean R-R interval have been reliably shown to index vagally-mediated PNS activity (Laborde et al., 2017; Tarvainen et al., 2019; Thayer et al., 2012), and SD1 has been significantly linked to RMSSD (Kubios Oy, 2019). The PNS index may thus provide a more robust index of PNS activity than any single metric alone.

Outliers defined by a z score of ± 3.29 (Field, 2013) were attributable to recording errors and removed from analyses. This led to the removal of two participants, both of whom had an ECG electrode fall off mid-recording. HRV data were assessed for normality via $z_{skewness}$. By convention, $z_{skewness} \geq \pm 1.96$ was considered significantly skewed at $p < .05$ (Field, 2013). As frequently found for HRV (Laborde et al., 2017), RMSSD, HF-HRV, and the PNS index all exhibited positive skew. It is customary to transform these values via the natural logarithm to adjust for non-normality (Laborde et al., 2017), which effectively corrected the skew.

2.3.2 Data Analysis Strategy

2.3.2.1 *Hypothesis One*

To analyze hypothesis one, Hayes' (2018a) PROCESS macro model 14 was used to examine whether the indirect effect of the MIST (X) on participant consumption (Y) through

HRV (*M*) was moderated in the second stage by dietary restraint (*W*; i.e., exerting its influence between *M* and *Y*). Figure 1 depicts the conceptual model illustrating hypothesis one. The index of moderated mediation (ab_3) quantifies the linear association between the indirect effect and putative moderator (Hayes, 2015). A significant index of moderated mediation denotes the mechanism's size or strength is increased or decreased in concert with changes in the moderator.

2.3.2.2 *Hypothesis Two*

Hayes' (2018a) PROCESS macro model 18 was employed to examine whether the indirect effect of the MIST (*X*) on consumption (*Y*) through HRV (*M*) was moderated in the second stage by an interaction between restraint (*W*) and frontal asymmetry during the MIST (*Z*), as depicted in Figure 2. A second-stage dual moderated mediation quantifies the linear relationship between a moderator (*W*) and an indirect effect at a given value of a second moderator (*Z*), thereby reflecting a three-way interaction between *M*, *W*, and *Z* (Hayes, 2018b). The index of dual moderated mediation (ab_7) quantifies the rate of change of the indirect effect of *X* on *Y* as *W* changes, conditioned on a specific value of *Z* (Hayes, 2018b).

2.3.2.3 *PROCESS Interpretation*

PROCESS uses an ordinary least squares (OLS) framework to estimate unstandardized regression coefficients (*b*), standard errors (*SE*s), direct and indirect effects, and the index of moderated mediation or dual moderated mediation. To discern whether indices are significant, PROCESS generates a 95% bootstrap confidence interval (CI), treating the original sample of size as a representation of the population of interest (Hayes, 2018a). To minimize estimate variation, it is recommended to set the number of bootstrap samples between 5,000 to 10,000 (Hayes, 2018a). In this study, 10,000 bootstrap samples were used, as there is minimal gain in precision beyond this level (Hayes, 2018a). When the CI does not straddle zero, but rather is entirely above or below, it reflects statistical significance (Hayes & Rockwood, 2017). Streiner (2006) suggests CIs also serve as a gauge of an effect's magnitude. If the CI is broad, statements about the effect's magnitude ought to be more tentative. A narrow CI indicates the SE of the estimate is small, suggesting it has been estimated precisely (Maxwell et al., 2008).

When an effect is moderated, analytical probing is used to ascertain values of the moderator for which the effect differs from zero (Hayes, 2018a). The pick-a-point approach can be implemented in PROCESS to compute conditional indirect effects at chosen values of the moderator. Hayes (2018a) recommends generating the conditional indirect effect at the 16^{th}, 50^{th}, and 84^{th} percentiles to reflect relatively low, moderate, and high levels of the moderator. These percentiles are preferable to $\pm$ 1 *SD* from the mean, as when a moderator is highly skewed, $\pm$ 1 *SD* may fall outside the range observed in the data and, if the moderator is normally distributed, this method is equivalent to $\pm$ 1 *SD* (Hayes, 2018a). If an index of dual moderated mediation is significant, the model can be probed by examining conditional indices of moderated mediation for values of both moderators to facilitate interpretation (Hayes, 2018b).

2.3.2.4 *Covariates*

As participants' average liking of the food items was significantly associated with the total amount of food consumed in g, $r = .42$, $p < .001$, liking was included as a covariate in each hypothesized model. Though hunger is often associated with consumption in the taste test paradigm (Robinson et al., 2017), none of the Grand Hunger Scale items were significantly related to consumption, including the time since last eating, $r = .13$, $p = .22$; subjective hunger, $r = -.01$, $p = .96$; amount of favourite food one could consume, $r = .19$, $p = .07$; or the time until their next meal, $r = .09$, $p = .39$. As a consequence, hunger was not included as a covariate. Baseline HRV and frontal asymmetry were included in the models as covariates, as appropriate.

2.3.2.5 ***Parametric Assumptions***

Prior to analyses, the data were assessed for violations of parametric assumptions. As moderated mediation is based on OLS regression, the models were required to fulfill the assumptions of homoscedasticity, normality, additivity and linearity, and independence of errors. Linearity and homoscedasticity were assessed visually via scatterplots of residuals against predicted values (Field, 2013) which revealed these assumptions were met. Heteroscedasticity-consistent SE estimates were also utilized in PROCESS based on recommendations by Hayes and Cai (2007), as this can offer greater assurance as to tests' validity and power.

With respect to normality, all variables were examined for outliers akin to ECG and EEG described above (Field, 2013). One outlier was identified on each of the EDE-Q-R and Preoccupation with Dieting scales. These outliers were replaced with the next highest value not meeting outlier criteria (Field, 2013). Continuous variables were similarly tested for normality using z_{skewness} (Field, 2013), and transformed as necessary. Given the nature of the data, there were no concerns about the independence of errors, thus this assumption was not tested.

2.3.3 Descriptive Statistics

Descriptive statistics related to pertinent psychometric, physiological, and demographic variables are presented in Table 2. Overall, participants consumed an average of 50.06 g (*SD* = 31.30) of food. Participants' food intake was positively skewed and subjected to a square root transformation, which corrected the skew. Although frontal asymmetry was negatively skewed, these scores were not further transformed. To apply transformations to negatively skewed variables, values must first be reversed, which can make interpretations unduly complicated (Field, 2013). Finally, the latent restraint factors Weight-Focused Restraint and Preoccupation with Dieting, and the restraint scales for the EDE-Q-R and EDI-3-DT, were significantly positively skewed and subjected to a square root transformation, which corrected the skew.

2.3.4 Group Comparisons

To explore whether there were any unintended differences across conditions, independent-groups, two-tailed *t*-tests were conducted for all continuous psychometric and demographic variables and chi-square tests were conducted for categorical variables. No significant differences emerged on age, marital status, ethnicity, BMI, depressive symptoms, oral contraceptive use, days since last onset of menses, latent restraint factors, or hunger, nor for EDE-Q-R, DEBQ-R, TFEQ-R, or RS scores. Despite random assignment and no significant differences across other restraint measures, there was a significant difference on the EDI-3-DT. Those in the stress condition reported significantly higher drive for thinness, $M = 2.74$, $SD = 1.37$, $t(95) = 2.07$[5], $p < .05$, than the control condition, $M = 2.14$, $SD = 1.48$. There were no significant differences between conditions with respect to baseline HRV or frontal asymmetry.

2.3.5 Manipulation Check for the MIST

To verify that HRV was reactive to the MIST as intended, a 2-between (condition [MIST stress vs. control]) × 2-within (block [baseline vs. MIST]) mixed factorial ANOVA was conducted for each HRV metric. It was expected that the stress condition would exhibit a significant decrease in HRV from baseline to the MIST, whereas the control condition would not show a change. Examining ln RMSSD, there was a significant block × condition interaction, $F(1, 95) = 16.04$, $p < .001$, with a large effect size ($\eta_p^2 = 0.14$), such that HRV was lower in the stress condition from baseline to the MIST. The block × condition interaction results were similar for HF-HRV, $F(1, 95) = 4.58$, $p < .05$, with a small-to-medium effect size ($\eta_p^2 = .05$) and for ln PNS

[5] All *t*-tests are reported as absolute values throughout this dissertation. As Streiner (2007) notes, the sign of the *t*-test solely depends on how the groups are coded, which is arbitrary. In this study, the groups were dichotomously coded, where 0 represented the control condition and 1 represented the stress condition.

index, $F(1, 95) = 29.13$, $p < .001$, with a large effect size ($\eta_p^2 = 0.24$).

Mixed factorial ANOVAs were followed up by paired samples *t*-tests in each condition to verify the expected pattern across blocks. As predicted, there was no significant difference in ln RMSSD between baseline and the MIST for the control condition, $t(49) = 1.78$, $p = .08$, while the stress condition exhibited a significant decrease, $t(46) = 3.58$, $p < .01$. There was similarly no significant difference across blocks in the control condition for ln HF-HRV, $t(49) = 1.74$, $p = .09$; however, HF-HRV did not significantly decrease in the stress condition, $t(46) = 1.35$, $p = .19$. Examining ln PNS index, there was a nonsignificant difference in the control condition, $t(49) = 0.93$, $p = .36$, and a significant decrease in the stress condition, $t(46) = 6.33$, $p < .001$.

To further ensure HRV significantly differed across conditions during the MIST, analyses of covariance (ANCOVAs) were conducted controlling for baseline HRV. Using ln RMSSD, the stress condition exhibited significantly lower ln RMSSD than the control condition, $F(1, 94) = 13.87$, $p < .001$, with a large effect size ($\eta_p^2 = 0.13$). Using other metrics, ln HF-HRV did not significantly differ across conditions, $F(1, 94) = 3.26$, $p = .07$, $\eta_p^2 = 0.03$, whereas ln PNS index was significantly lower in the stress condition, $F(1, 94) = 28.43$, $p < .001$, with a large effect size ($\eta_p^2 = 0.23$). It was thus determined that the MIST stress condition effectively elicited significant parasympathetic withdrawal when examining ln RMSSD and ln PNS index, but not for HF-HRV. As such, hypotheses were only examined utilizing ln RMSSD and ln PNS index.

ANCOVAs were also performed to explore the impact of the MIST on subjective stress and confidence in mathematical ability controlling for baseline levels. As expected, those in the stress condition reported significantly higher stress after the MIST, $M = 26.19$, $SD = 3.44$, $F(1, 94) = 51.89$, $p < .001$, than the control condition, $M = 19.14$, $SD = 5.64$, with a large effect size, $\eta_p^2 = 0.36$ and significantly lower mathematical confidence, $M = 26.47$, $SD = 24.37$, $F(1, 94) =$

12.12, than the control condition, *M* = 37.38, *SD* = 23.05, with a medium-to-large effect size, η_p^2 = 0.11. Thus, the MIST successfully induced both physiological and psychological stress.

2.3.6 Simple Mediation Model

Prior to analyzing hypothesis one and two, data were subjected to Hayes' (2018a) PROCESS macro model 4 to examine whether HRV mediated the relationship between the MIST and participant consumption in a simple mediation without moderators. This analysis revealed a significant indirect effect via ln RMSSD, *ab* = -.390, *SE* = .199, 95% CI [-.841, -.061]. However, contrary to expectations, the regression coefficient was positive between ln RMSSD and participant consumption, *b* = 1.88, $p < .01$, indicating lower ln RMSSD was associated with lower consumption. A similar pattern emerged for the PNS index, which also yielded a significant indirect effect, *ab* = -.575, *SE* = .238, 95% CI [-1.055, -.121].

2.3.7 Hypothesis One

Hypothesis one examined whether the indirect effect of the MIST (*X*) on participant consumption (*Y*) through ln RMSSD during the MIST (*M*) was moderated in the second stage by restraint (*W*). There was a significant index of moderated mediation for both Weight-Focused Restraint, ab_3 = .170, *SE* = .074, 95% CI [.043, .330], and Calorie Counting, ab_3 = .057, *SE* = .022, 95% CI [.021, .107], but not for Preoccupation with Dieting, ab_3 = .091, *SE* = .064, 95% CI [-.032, .224]. The indices of moderated mediation mean that the indirect effect via ln RMSSD increased by 0.170 units as Weight-Focused Restraint increased by one unit and 0.057 units for Calorie Counting. As the indirect effect was negative in the simple mediation model, this means the strength of the indirect effect was reduced as these latent restraint factors increased. The moderated mediation can be further understood by examining the paths in the model.

Tables 3 and 4 display unstandardized regression coefficients, SEs, and 95% CIs using

Calorie Counting and Weight-Focused Restraint as the moderator, respectively. Akin to the simple mediation, the overall path between ln RMSSD (*M*) and consumption (*Y*) was significant and positive, indicating lower ln RMSSD led to lower consumption. The $M \times W$ coefficient for Weight-Focused Restraint, $b_3 = -.816$, $p < .01$, denotes that for two cases that differed by one unit on ln RMSSD (*M*), consumption increased by 0.816 units as Weight-Focused Restraint (*W*) increased by one unit. Thus, as restraint increased, lower HRV was associated with greater consumption. The $M \times W$ coefficient for Calorie Counting, $b_3 = -.275$, $p < .001$, exhibited a similar pattern. However, it is important to probe conditional indirect effects to ascertain the levels of the moderator for which the indirect effect is significant.

Table 5 presents the conditional indirect effects of *X* on *Y* at values of the latent restraint factors corresponding to the 16^{th}, 50^{th}, and 84^{th} percentiles. Examining the conditional indirect effects for Weight-Focused Restraint and Calorie Counting, it is evident that the indirect effect was only significant among those at the 16^{th} and 50^{th} percentiles, but not at the 84^{th} percentile of restraint (see Figure 5 for a graphical representation). Thus, ln RMSSD did not significantly mediate the relationship between the MIST and consumption for those with higher restraint.

Using the conventional restraint scales, the model was significant for the EDE-Q-R, $ab_3 = .216$, $SE = .126$, 95% CI [.014, .508], TFEQ-R, $ab_3 = .055$, $SE = .021$, 95% CI [.022, .103], and DEBQ-R, $ab_3 = .308$, $SE = .119$, 95% CI [.102, .565], but not the EDI-3-DT, $ab_3 = .092$, $SE = .058$, 95% CI [-.012, .214], or RS, $ab_3 = .006$, $SE = .016$, 95% CI [-.030, .035]. The pattern of conditional indirect effects for the EDE-Q-R, TFEQ-R, and DEBQ-R was similar to Weight-Focused Restraint and Calorie Counting. Conclusions remained relatively unchanged using ln PNS index as the mediator, except that the model was no longer significant for the EDE-Q-R.

2.3.8 Hypothesis Two

The indirect relationship between the MIST (*X*) and participant consumption (*Y*) via ln RMSSD (*M*) moderated by Weight-Focused Restraint (*W*) was further moderated by frontal asymmetry (*Z*), ab_7 = 1.595, *SE* = 0.866, 95% CI [.098, 3.545]. The index of dual moderated mediation reflects the fact that as frontal asymmetry increased by one unit, denoting a shift towards greater left frontal asymmetry, Weight-Focused Restraint's moderation of the indirect effect increased by 1.595 units. The dual moderated mediation model was not significant for Preoccupation with Dieting or Calorie Counting. The dual moderated mediation for Weight-Focused Restraint was probed at the 16th, 50th, and 84th percentiles of both moderators.

Overall, the model was only significant for the 84th percentile of frontal asymmetry, reflecting greater left frontal asymmetry, *b* = .233, *SE* = .093, 95% CI [.059, .428]. Exploring the conditional indirect effects at the 84th percentile of frontal asymmetry and 16th, 50th, and 84th percentiles of Weight-Focused Restraint revealed that the indirect effect was only significant for those at the 16th percentile, *b* = -.676, *SE* = .306, 95% CI [-1.340, -.147]. By contrast, it was not significant for those at the 50th, *b* = -.325, *SE* = .223, 95% CI [-.798, .057], or 84th percentile, *b* = -.052, *SE* = .208, 95% CI [-.498, .341]. Model 18 was also conducted with the conventional scales and was only significant for the DEBQ-R. Conclusions remained unchanged with the PNS index. Indices of dual moderated mediation for all restraint scales and factors are shown in Table 6. Table 7 shows the regression coefficients in the model for Weight-Focused Restraint.

2.4 Discussion

The current study sought to examine whether self-regulatory capacity, as indexed via HRV (Holzman & Bridgett, 2017; Zahn et al., 2016), mediates the relationship between stress and consumption to discern whether this indirect effect explains restrained eaters' disinhibited eating. The current study also strived to isolate an individual difference variable that might alter the strength of this association to help clarify differences in restrained eaters' vulnerability to disinhibition. In light of the process model of ego depletion, it was hypothesized motivational orientation, indexed via frontal asymmetry (E. Smith et al., 2017), might moderate this model. While the results did not support hypotheses, a number of intriguing findings emerged.

2.4.1 Low HRV Prompted Reduced Consumption

Interestingly, HRV significantly mediated the relationship between a laboratory stressor and the amount of food participants consumed, regardless of dietary restraint, such that lower HRV induced by the task for those in the stress condition significantly reduced consumption. This finding was somewhat unexpected. While no formal hypothesis was put forth for this model, it was expected that low HRV would lead to greater consumption amongst all individuals given conclusions drawn from research examining eating in response to stress and negative moods (e.g., Araiza & Lobel, 2018; Cardi et al., 2015). Nevertheless, the literature on stress-induced eating is nuanced. Individuals exhibit heterogeneous changes in food intake under stress, such that some tend to eat more, whereas others consume less (Greeno & Wing, 1994).

It has been posited the type of stressor may dictate whether intake increases or decreases, particularly with respect to its intensity (Macht, 2008). Intense stressors seem to evoke decreased intake, whereas less intense stressors appear to increase intake (Macht, 2008). As Macht (2008) postulates, emotions high in arousal or intensity might suppress eating due to incompatibility between physiological activation and concordant action tendencies. High intensity emotions activate the autonomic nervous system and thus evoke physiological changes that reduce appetite and inhibit food intake in normal eaters, such as slowed gastric emptying (Evers et al., 2018) and increased blood glucose (Herman & Polivy, 1984). It is possible that the stress task in this study may have elicited a high degree of arousal and could have been a relatively intense acute stressor, as it evoked significant physiological and subjective stress. Certain elements of the specific stress task utilized may have been responsible for this particularly heightened physiological and emotional stress response.

The laboratory stressor employed included criticism and disapproval from the researcher, and consequently, constituted social-evaluative stress. In addition, it was likely experienced as uncontrollable (Dickerson & Kemeny, 2004). As the stress condition purposefully restricted the time to respond to items to induce failure, participants could not surpass a given level of performance regardless of how hard they tried. These features of the stressor are important as a meta-analysis by Dickerson and Kemeny (2004) reported acute psychological stressors in the laboratory that contain both uncontrollable and social-evaluative elements evoke the strongest cortisol and adrenocorticotropin hormone (ACTH) responses. The stress task that was used thus likely evoked intense arousal. Anecdotally, a handful of participants did in fact cry during the stress condition, which may also substantiate the supposition that it was experienced as intensely stressful. This intensity may thus have been responsible for creating the suppression evident in individuals' consumption across the entire sample. To sum, although it was somewhat unexpected that low HRV prompted a significant reduction in food intake in the sample as a whole, it is not entirely unsurprising when considering these contextual factors. Further reasons for the suppression of intake via low HRV will be explored in Chapter 5. The discussion now turns towards a consideration of the results derived from hypotheses one and two pertaining to the moderating impact of dietary restraint and frontal asymmetry, respectively.

2.4.2 The Indirect Effect via HRV Among Restrained and Unrestrained Eaters

Analysis of hypothesis one revealed that the indirect effect of the laboratory stressor on consumption via HRV was significantly moderated by dietary restraint. This indirect effect emerged when restraint was represented by Hagan et al.'s (2017) Weight-Focused Restraint and Calorie Counting factors, but not Preoccupation with Dieting. Differences across these factors will be discussed in section 2.4.5 and Chapter 5. Nevertheless, despite the model's significance, the results did not align with predictions. Upon examining the conditional indirect effects, it was evident that whereas HRV significantly mediated the relationship between the laboratory stressor and consumption among those with lower dietary restraint (i.e., at the 16^{th} and 50^{th} percentiles in the sample), the indirect effect was nonsignificant among more highly restrained eaters (i.e., at the 84^{th} percentile). Individuals higher in restraint did not appreciably change their eating in accordance with their stress-induced reduction in HRV. To sum, analysis of hypothesis one revealed three unexpected findings: (1) low HRV significantly reduced consumption for participants with lower restraint; (2) more highly restrained eaters did not exhibit disinhibition in response to the MIST; and (3) low HRV was not significantly related to restrained eaters' intake.

Given the aforesaid findings on stress-induced eating in the general population (e.g., Araiza & Lobel, 2018), it was initially anticipated unrestrained eaters would increase their intake in response to stress via low HRV, though to a lesser extent than restrained eaters. However, in retrospect, this prediction was somewhat misguided. Previous studies in the restraint literature have likewise found unrestrained eaters significantly reduce their intake in response to manipulations of stress or threat (e.g., Heatherton et al., 1991; Herman & Polivy, 1975; Ward & Mann, 2000). Lowe and Kral (2006) indeed note the majority of studies reveal restrained eaters tend to increase and unrestrained eaters tend to decrease food intake in high relative to low stress conditions. For example, in a high anxiety condition that entailed the threat of electric shock, Herman and Polivy (1975) found unrestrained eaters ate significantly less. It is further interesting to note that, similar to the current study, although restrained eaters in their study consumed more in the high anxiety condition, the difference was not significant (Herman & Polivy, 1975).

Heatherton et al. (1991) uncovered somewhat similar findings to the current study and Herman and Polivy (1975), though only in their physical fear threat condition (i.e., anticipation of electric shock). Participants were randomized to one of four conditions, including physical fear threat; two ego threat conditions, one of which entailed failing an easy concept-formation task and the other involving anticipating giving a speech to an evaluative audience; and a control condition. Unrestrained eaters consumed significantly less when anticipating electric shock, whereas restrained eaters slightly increased their eating, though not significantly so (Heatherton et al., 1991). In both ego threat conditions, however, restrained eaters ate significantly more, whereas unrestrained eaters ate less but not to a significant extent (Heatherton et al., 1991).

On the basis of their findings, Heatherton et al. (1991) posited that to provoke disinhibition, a stressor must constitute an ego threat rather than physical fear. However, in the current study, the laboratory stressor produced a similar effect to the physical fear threat despite entailing an ego threat vis-à-vis task failure and negative social feedback. Heatherton et al. (1991) further proposed anticipating electric shock significantly decreased unrestrained eaters' intake because it produced autonomic arousal, stating unrestrained eaters were more responsive to such effects though the basis of this inference was not clear. It might be argued that the accompanying physiological arousal may likewise begin to suppress restrained eaters' eating and thereby attenuate disinhibition. Schotte (1992) formulated a similar conclusion, proposing that autonomic activation spurred by physical threats may effectively offset affective pressures towards disinhibition, resulting in minimal impact on restrained eaters' intake. Among unrestrained eaters, by contrast, autonomic effects would be unopposed and thus significantly reduce consumption. Despite not entailing a physical threat, the stress task utilized may have had a comparable effect given that the stress condition elicited significant autonomic arousal as indexed by HRV. Indeed, Schotte (1992) likewise concluded that the key to understanding how food intake is impacted may be participants' cognitive, affective, and physiological response to a manipulation, rather than focusing on the specific manipulation (i.e., physical versus ego threat).

While autonomic arousal induced by the stress task may explain the lack of disinhibition in highly restrained eaters, other tasks that have caused disinhibition also evoke autonomic arousal. As noted earlier, Castaldo et al. (2015) found tasks that induce disinhibition such as the Stroop Colour-Word task and speech anticipation tasks (e.g., Heatherton et al., 1991; Lattimore & Maxwell, 2004; Wallis & Hetherington, 2004) reduce HRV. This suggests tasks in other studies might have also elicited autonomic arousal without suppressing disinhibition. With that said, Brugnera et al. (2018) found the MIST induced a stronger cardiovascular response than the Stroop-Colour Word task and a speech task. Though a tentative conjecture, the current results may suggest there is a threshold of autonomic activation beyond which the sequelae of physiological arousal exert potent countervailing forces against the tendency towards disinhibition. However, this remains an empirical question for future studies. Results from the current study also prompted consideration of the reliability of the disinhibition effect.

2.4.2.1 *Critically Questioning the Disinhibition Effect*

Though the current study did not reveal a significant disinhibition effect among restrained eaters, it is important to highlight that analyses herein differ from those traditionally conducted in the literature on restraint theory. In the majority of studies, restraint has been dichotomized based on either a median split (e.g. Herman & Polivy, 1975; Royal & Kurtz, 2010; Wallis & Hetherington, 2004) or cut-off scores employed in previous studies that uncovered a significant difference in eating behaviour between groups defined thusly (e.g., Heatherton et al., 1991; Ward & Mann, 2000). As MacCallum et al. (2002) emphasize, however, dichotomizing continuous individual-differences variables lacks appropriate justification both conceptually and statistically. Of particular importance, when there are two independent variables, such as in the case of restraint status and experimental condition, dichotomization can overestimate effect size and lead to Type I error, whereby spurious significant effects might emerge (MacCallum et al., 2002). The current study thus did not create categorical groups to reflect restraint status.

However, to explore the supposition that dichotomization may alter findings in such studies, the RS was used to categorize the sample into restrained and unrestrained eaters, as it has been most frequently employed to examine disinhibition. Heatherton et al. (1991) noted the typical cut-off for the RS is 15 or 16; however, the median has also been used (e.g., Cools et al., 1992). Supplementary one-way ANOVAs were thus conducted, dichotomizing the RS based on each cut-off. Unsurprisingly, findings differed depending on how the groups were defined. Employing a median split yielded a p value of 0.15 for the interaction between experimental condition and restraint status, a cut-off score of 15 yielded a p value of 0.08, and a cut-off score of 16 yielded a p value of 0.05. Thus, conclusions may differ depending on the cut-off used. By comparison, when restraint was conceptualized as a continuous variable via either the restraint factors or conventional scales, no interactions were significant in supplementary moderations.

There is also evidence in previously published studies that findings may change when restraint is treated continuously. In a study by Heatherton et al. (1993), significant disinhibition was reported when restraint was dichotomized; however, they indicated in a footnote that when treating restraint as a continuous variable in a multiple regression, the effect was "marginally significant" (p. 57) with the p value specified as < 0.10. Stated more accurately, the disinhibition effect was not significant. While some studies have found significant disinhibition when treating restraint as a continuous measure and dimensional construct (Boyce & Kuijer, 2014; Cools et al., 1992; Hofmann et al., 2007), such studies are strikingly scarce in the literature. As such, it is unclear to what extent disinhibition and differences in consumption ought to be expected when restraint is treated continuously and data is analyzed using regression-based statistical analyses.

Regardless, it is evident from Figure 5 that those who exhibited the highest restraint did not consume more when they exhibited lower ln RMSSD relative to those with the highest restraint who exhibited higher ln RMSSD. When examining those at the 84^{th} percentile of Weight-Focused Restraint and Calorie Counting, there was only a slight difference in consumption that suggested a slight decrease as HRV decreased, rather than an increase. It is interesting to note, however, that Figure 5 would also suggest those with the highest restraint (i.e., the 84^{th} percentile) who exhibited lower ln RMSSD (i.e., towards the left side of the *x*-axis) ate more than less restrained individuals with lower ln RMSSD. Moreover, among those who exhibited higher ln RMSSD, those highest on restraint ate the least, while those lowest on restraint ate the most. These results emphasize that conclusions about the presence of disinhibition could vary depending on the comparison undertaken. If comparing those who exhibit higher versus lower restraint within a stress condition (i.e., comparing across those with lower HRV), restrained eaters seem to have become disinhibited due to eating more than their unrestrained counterparts. However, if comparing more highly restrained eaters in a stress condition relative to a control condition (i.e., comparing the 84^{th} percentile of restraint across low versus high HRV), the data suggests restrained eaters did not eat more when stressed.

Of relevance, Polivy and Herman (2020) recently called into question the notion that restrained eaters can be concluded to have overeaten or become disinhibited solely if they consumed more than unrestrained eaters in the same condition or even compared to restrained eaters in a control condition. In fact, despite developing and advancing restraint theory, Polivy and Herman's (2020) commentary highlights there may be more nuance to adequately capturing disinhibited eating. Controversies raised by Polivy and Herman (2020) in regards to the conceptualization of overeating and disinhibition will be discussed in greater depth in Chapter 5. Notwithstanding these controversies, it is also vital to reflect on what the current results appear to connote vis-à-vis the hypothesized role of self-regulation in prompting disinhibition.

2.4.2.2 *The Role of Self-Regulatory Capacity*

When focusing on the pattern of consumption displayed in Figure 5, it may be tempting to construe these findings as concordant with the hypothesized role of HRV as a causal agent reflective of self-regulatory capacity. Examining those with higher HRV along the *x*-axis, and presumably greater self-regulatory capacity, those with the highest level of restraint do appear to eat the least compared to their less restrained counterparts. On the contrary, examining those with lower HRV along the *x*-axis, when self-regulatory capacity would expectedly be attenuated, more highly restrained eaters seem to eat the most. However, if HRV reflected self-regulatory capacity with regards to the ability to modulate food intake and maintain dieting goals in this context, restrained eaters would be anticipated to consume more food when they exhibited low HRV relative to high HRV. As previously highlighted, however, this was not the case. Beyond its potential to serve as a biomarker of self-regulation, one must also keep in mind that reduced HRV can merely reflect vagal withdrawal in the service of responding to an acute stressor. Thus, low HRV may be accompanied by changes in behaviour and physiology that align with the fight-or-flight response (Porges, 2009), as articulated in section 2.4.1. The uncoupling of HRV and consumption in more restrained eaters could reflect their theoretical disconnection from physiological cues in dictating their intake (Boon et al., 2002; Herman & Polivy, 1983). Restrained eaters' tendency towards greater eating when exhibiting low HRV might also suggest they experience an underlying approach bias towards food when stressed that could counter the physiological changes that normally suppress intake, though this may not be a conscious process.

The reader is reminded that Wagner et al.'s (2012) study discussed in section 2.1.2 found negative mood induction in highly restrained eaters enhanced activity in the OFC, a brain region associated with processing the hedonic reward value of food (Kringelbach, 2005), upon viewing images of appetizing foods. Wagner et al.'s (2012) study indicates distress seems to enhance the brain's sensitivity to reward-related appetitive cues in restrained eaters. Enhanced perception of the reward value of food may contribute to restrained eaters' greater inclination towards eating or rather their lack of significant suppression in intake when faced with stress or negative affect. It is further interesting to note that Wagner et al. (2012) found activity was specifically increased in the left OFC. As left frontal asymmetry converges with left OFC activation during reward anticipation (Gorka et al., 2015), the results of hypothesis two are relevant to consider.

2.4.3 The Moderating Role of Frontal Asymmetry

Hypothesis two revealed that the indirect association between the laboratory stressor and consumption via HRV moderated by Weight-Focused Restraint was further moderated by frontal asymmetry. Once again, however, results were not in line with predictions. It was originally hypothesized the predicted link between low HRV and increased consumption would be strongest for those with higher dietary restraint who exhibited greater left frontal asymmetry. As hypothesis one did not reveal a significant link between HRV and consumption in those with elevated restraint, it is perhaps unsurprising that hypothesis two was not borne out as predicted. As the index of conditional moderated mediation was only significant at the 84th percentile of frontal asymmetry, restraint's moderation of the indirect effect was contingent on greater left frontal asymmetry. These results suggest that something about greater left frontal asymmetry explains why dietary restraint moderates the indirect effect.

Given that left frontal activity is associated with an approach motivation (E. Smith et al., 2017) and left OFC activation (Gorka et al., 2015), the current findings may indirectly support the conjecture that a motivational bias to approach food in restrained eaters could counteract the impact of autonomic arousal in suppressing food intake. Akin to Wagner et al.'s (2012) findings, restrained eaters with greater left frontal asymmetry during the MIST might have experienced sensitization of the brain's reward system to food and felt prompted to gratify their appetitive desires, even despite mechanisms that typically elicit appetite suppression. This can be understood to reflect hedonic rather than homeostatic eating (Berthoud, 2011). As noted in section 2.1.2.1, left frontal asymmetry has also been related to hedonic hunger and appetitive responsivity to food (Ochner et al., 2009; Winter et al., 2016).

For restrained eaters who exhibited greater right frontal asymmetry during the laboratory stressor, the predominant tendency to withdraw (Pizzagalli et al., 2005) or avoid aversive stimuli (E. Smith et al., 2017) may have facilitated disengagement from food temptations. Support for this conjecture is derived from a study by Fregni et al. (2008) wherein a manipulated increase in right frontal asymmetry via transcranial direct current stimulation of the DLPFC significantly decreased food craving and visual attention towards tempting foods relative to sham stimulation. Although Fregni et al. (2008) did not assess restraint, their findings suggest right frontal asymmetry may be associated with reduced reward valuation of food. This may explain why those with higher restraint who exhibited greater right frontal asymmetry demonstrated a pattern similar to those with lower restraint. Conflicting pressures to approach food may have been relatively absent due to decreased attention to food, and thus, physiological changes that prompt appetite suppression may have been unopposed. On the contrary, left frontal asymmetry is associated with attentional narrowing (Gable & Harmon-Jones, 2010). For those with high restraint and greater left frontal asymmetry, it is conceivable that this may have led to greater attention to food. Indeed, attentional and approach biases are conceptualized to reflect closely related facets of an underlying responsivity to cues of food reward (e.g., Brignell et al., 2009).

It is additionally noteworthy that the moderating influence of dietary restraint among those with greater left frontal asymmetry was similar to the pattern of results that emerged when only including restraint as a moderator within the mediation model. In both circumstances, the indirect effect was nonsignificant in those with the highest levels of restraint while, among less restrained eaters, low HRV prompted a significant reduction in consumption. The factors that underlie the moderating influence of left frontal asymmetry may consequently predominate when explaining why restraint moderates the association between HRV and consumption. Given possible implications of left frontal asymmetry on attentional processes, and theoretical and empirical links between HRV and attention (e.g., Miskovic & Schmidt, 2010; Porges, 1995; Thayer & Lane, 2000), it is plausible that attentional bias to food could be a missing link in understanding the results of the current study. Study Two will examine this conjecture further.

2.4.4 Limitations and Future Directions

The results herein are limited by the fact that the majority of the sample self-reported their ethnicity as Caucasian (i.e., 73.8%), reflecting minimal representation of those from other ethnic groups. Though this aligns with the population of undergraduate students at Lakehead University in psychology courses, it remains unknown whether results will generalize to those from other ethnic groups. It might also be considered a limitation that the current study included those outside the normal BMI range (i.e., 18.5 < BMI < 24.9 kg/m^2; Centers for Disease Control and Prevention, 2020), with a substantial proportion in the overweight or obese range. Forbush et al. (2020) recently demonstrated that many of the restraint scales show differential item functioning across healthy weight individuals and those with a weight in the overweight or obese range. Item bias is strongest for the RS, such that 60% of items exhibit bias, with low to moderate bias in the EDI-3-DT, TFEQ-R, and DEBQ-R. Only the EDE-Q-R showed no bias (Forbush et al., 2020). Differential item functioning might explain why only certain restraint factors and conventional restraint scales were found to significantly moderate the indirect effect.

To reiterate, the moderated mediation was only significant with Hagan et al.'s (2017) Weight-Focused Restraint and Calorie Counting, but not Preoccupation with Dieting. Weight-Focused Restraint is comprised of items from the DEBQ-R and EDE-Q-R, and Calorie Counting is derived from TFEQ-R items (Hagan et al., 2017), incorporating scales with lower item bias (Forbush et al., 2020). Preoccupation with Dieting, on the other hand, constitutes items from the RS and EDI-3-DT (Hagan et al., 2017). As 37.1% of participants in analyses of hypothesis one and 39.1% in hypothesis two had a weight in the overweight or obese range, the high item bias in the RS may have detracted from the ability to find a moderated mediation effect utilizing the RS or Preoccupation with Dieting. While the EDI-3-DT demonstrates low item bias (Forbush et al., 2020), the difference between conditions on EDI-3-DT scores could further account for the lack of moderation by Preoccupation with Dieting and the EDI-3-DT. It is unclear whether the results from this study would replicate in a sample that only included those with a healthy weight apropos the specific restraint scales and latent factors that moderate the indirect effect.

Although the study only included females given that dietary restraint is more prominent in females (de Witt Huberts et al., 2013), and the population from which the sample was drawn was largely female, this inclusion criteria limits the generalizability of these findings to males. It can be surmised that if a psychophysiological mechanism such as HRV mediates the relationship between stress and intake, even if acting as a proxy for self-regulation, this effect may not be specific to females. It is questionable, however, whether the moderation by restraint would differ due to differences in the prevalence or variability of restraint in males (Polivy et al., 2020). Future studies ought to explore whether similar conclusions are derived among males.

In accordance with earlier conjectures, future studies could examine whether tasks that generate varying levels of physiological arousal differentially affect the emergence of disinhibited eating. If so, this may explain disparate findings in restrained eaters' vulnerability to disinhibition across studies, as many have used different manipulations. Beyond variation across tasks, individuals' HRV reactivity can also differ in response to the same task (Laborde et al., 2018). It is possible that rather than mediating disinhibition, individuals' HRV reactivity may have moderated their proclivity towards disinhibition. While such a moderation was not evident in the current study, perhaps HRV reactivity may be more important at a within-subjects level. For example, Ranzenhofer et al. (2016) found low HRV prior to eating was significantly associated with loss-of-control eating at a within-subjects level, but not a between-subjects level. Future studies could employ a similar methodology wherein ecological momentary analysis and ambulatory Holter monitoring of HRV are used to ascertain the potential causal role of low HRV in eliciting disinhibition relative to "normal" eating episodes in restrained eaters. Nevertheless, the tentative conclusion drawn from the current study is that restrained eaters' intake may not necessarily become excessive in absolute terms. Rather, it simply may not be suppressed by physiological stress and related corollaries in the same way as less restrained eaters.

Chapter 3. Linking Study One and Study Two

As described in Chapter 1, the current program of research originally conceived that Study Two would seek to examine whether increasing heart rate variability (HRV) post-stress could attenuate the likelihood of disinhibited eating. The foundation of Study Two was thus unduly contingent on supporting the hypothesis that low HRV would prompt restrained eaters' disinhibited eating in the face of stress. As Study One did not support this hypothesis, Study Two was no longer tenable as initially proposed. Study Two was thereby reconceptualized to provide clarity to the unexpected results revealed in Study One, which ultimately provoked two broad questions: (1) Why did low HRV prompt reduced food consumption for individuals in the stress condition overall? and (2) Why was this effect only significant for those low in dietary restraint and not for more restrained eaters? Study Two strived to identify a possible underlying mechanism that might help understand the HRV-mediated decrease in eating after stress among less restrained eaters and the absence of an HRV-mediated effect on food in restrained eaters.

The central notion underpinning the reformulation of Study Two was that the simple mediation observed in Study One may be attributable to the impact of low HRV on individuals' proclivity to selectively attend to food when faced with a stressor. More specifically, it was proposed there may be a serially mediated effect, such that low HRV evoked by the stressor might attenuate attentional bias to food, and thereby prompt reduced ad libitum consumption of palatable foods (Figure 7). This serial mediation model was invoked to explain observed reductions in intake associated with low HRV across participants overall. Chapter 2 briefly mentioned this conjecture in accordance with findings pertaining to frontal asymmetry and theoretical notions that stress is associated with attentional narrowing (Porges, 1995), as expanded on below. However, the simple mediation model was also moderated by dietary restraint. If attentional bias to food accounts for the link between reduced HRV and consumption, why would only those with lower restraint reduce their attentional bias to food via HRV? There is arguably reason to speculate that low HRV may differentially impact attentional bias to food depending on one's level of restraint.

As restrained eaters typically display a heightened attentional bias to food compared to unrestrained eaters (Polivy & Herman, 2017) and are prone to eat in response to stress (Stroebe, 2008), their likelihood of attending to food when faced with stress may differ from their less restrained counterparts. For restrained eaters, stress may be conferred with incentive salience through prior associations to the subsequent consumption of food in episodes of disinhibition (Berridge, 2009). As a result, stress may enhance attention to food (Berridge, 2009). It is also possible food could be perceived as a "threat" by highly restrained individuals during periods of stress due to past episodes of disinhibition, as it threatens their goal of controlling their intake. Whether due to incentive salience or perceived threat, it is contended that stress may heighten attention to food for restrained eaters, which may thereby encourage greater consumption relative to unrestrained eaters. However, as seen in Study One, their consumption may not necessarily become incredibly excessive, particularly depending on the level of arousal associated with the stressor. In the serial mediation model proposed above, restraint would thus be expected to exert a moderating role between HRV and attentional bias to food (Figure 10).

It is interesting to highlight that the hypothesized role of attentional bias to food parallels the process model of ego depletion (Inzlicht & Schmeichel, 2012). Study One focused on the model's proposed shift in motivational orientation due to ego depletion. However, ego depletion is also posited to manifest in a shift towards enhanced attention to palatable food cues (Geisler et al., 2016). In addition, including attentional bias to food as a causal link in predicting restrained eaters' consumption partly accords with Heatherton and Baumeister's (1991) escape theory of "binge eating," conceptualized as eating that results from the disinhibition of dietary restraint. Escape theory posits stress-induced eating occurs via one's desire to escape a negative emotional state and aversive self-awareness, which leads to cognitive narrowing to sensations and stimuli in the immediate environment (Heatherton & Baumeister, 1991). This cognitive narrowing could lead to enhanced attention to food-related cues. Unlike Heatherton and Baumeister (1991), however, Study Two only aims to identify the mechanism behind stress-induced eating patterns rather than explicitly inferring the function of such behaviour. Theoretical foundations implicating a link between attentional processes and HRV under stress are articulated below.

3.2 Theoretical Links Between HRV and Attentional Bias

Existent theories of HRV form the basis of the fundamental proposition that attentional bias to food may be influenced by low HRV in the face of stress. Both the neurovisceral integration model (Thayer & Lane, 2000) and Porges' (1995) polyvagal theory converge on the notion that HRV is inextricably linked with attentional processes. As Thayer and Lane (2000) highlight, an organism's ability to select what is meaningful to attend to while disregarding irrelevant information is crucial for an organism's survival. The determination as to what information is meaningful depends on the impact it has for the organism's well-being and survival. The ability to effectively shift and sustain attention is thus integral to an organism's ability to self-regulate and behave optimally (Porges, 1992; Thayer & Lane, 2000).

The neurovisceral integration model (Thayer & Lane, 2000) and Porges' (1995) polyvagal theory propose vagal regulation of the heart enables individuals to quickly adjust cardiac parasympathetic influences in a manner that facilitates attentional engagement or disengagement with their sensory environment based on environmental demands (Appelhans &

Luecken, 2006). In the face of a “survival threat” or stress, polyvagal theory posits an organism narrows its attention towards salient environmental cues to facilitate adaptive reactivity and effective responding to the demands of the threat (Porges, 1995). As previously discussed, organisms likewise demonstrate a reduction in HRV when a stressor is encountered to respond to the threat (Porges, 1995). This suggests a coupling between attentional narrowing and low HRV that aims to enable adaptive coping. As the aforementioned theories suggest, studies have found sustained attention is, in fact, associated with a reduction in HRV (Thayer & Lane, 2000).

Narrowed attention associated with low HRV in the face of stress may lead to a bias to attend to whatever stimuli is perceived to pose a threat in one’s milieu (Miskovic & Schmidt, 2010). Attending to any cues of potential threat that are present and remaining vigilant for the emergence of additional threat-related cues would be evolutionarily adaptive to ensure one’s safety. To ensure information relevant to the threat is fully perceived and attended to, it may also be adaptive to reduce attention towards appetitive stimuli. Considering the evolutionary milieu in which attentional systems developed, opportunities for food or mating could not be capitalized on in the presence of a dangerous predator. Safety would be contingent on escaping, fighting the predator, or freezing in place (Porges, 1995), all of which require one to be fully aware of the location and movement of the predator, necessitating one’s careful attention. Thayer and Lane (2000) note low HRV is also associated with poor attentional control. Consequently, attention might be narrowed to threat-related cues in the environment with minimal ability to redirect attention to other stimuli deemed irrelevant to the threat. Given that all individuals tend to exhibit a baseline attentional bias to food (e.g., Hollitt et al., 2010), low HRV may attenuate this existing bias as a corollary of enhanced attention towards currently perceived threats. Insight into the tenable link between HRV and attention to food in response to stress can also be derived from emergent details about the hierarchical basis of neurovisceral integration.

3.2.1 *The Hierarchical Basis of the Neurovisceral Integration Model*

In explicating the hierarchical basis of the neurovisceral integration model, R. Smith et al. (2017) describe that a multi-level hierarchy of structures in the central autonomic network (CAN) contribute to vagal control and ultimately allow for coordination across cognitive, affective, autonomic, and behavioural responses. The network is organized such that lower levels of the hierarchy primarily respond to present metabolic needs and regulate energy expenditure by integrating current incoming information from the body. Higher levels in the CAN regulate energy expenditure in the service of both present and expected future metabolic needs by integrating information from a wider range of sources (e.g., exteroceptive perception, memory, etc.) so as to mobilize resources to meet challenges across short and long timescales in a timely fashion. As a consequence, the brain is continually attempting to predict the pattern of sensory input that may arrive next. These predictions are based on current sensory input, as well as prior probability distributions (i.e., “priors”) represented in an internal model comprised of hypotheses about cause and effect relationships in one’s world. The CAN strives to minimize prediction errors, which occur when sensory input deviates from what was predicted in a given context. If a prediction error occurs, such as encountering an unpredicted acute stressor, the error signal propagates through upward connections to higher processing areas in the brain to essentially revise the internal model until new predictions are derived. In the case of a stressor, these error signals would elicit a change in the priors (i.e., beliefs) used to predict the likely state of the world, increasing the strength of priors for “threat” or “danger.” These new expectations and appraisals then alter “precision estimates” (i.e., the sensory information given the most weight), which subsequently drive the autonomic, endocrine, cognitive, attentional, and behavioural changes perceived to be most adaptive in the appraised context (R. Smith et al., 2017).

As R. Smith et al. (2017) note, priors for heart rate and blood pressure patterns during an acute stressor are represented at lower levels in the hierarchy (e.g., cardiac vagal changes), whereas priors for cognitive appraisals of a stressor are represented at higher levels. Cardiac vagal changes lower in the hierarchy influence higher levels, such as the amygdala, and thus enable HRV to impact the organization of behaviour (R. Smith et al., 2017). As noted in Chapter 1, the amygdala is involved in detecting salient stimuli. The amygdala's connections with higher association and sensory cortices then facilitate attention to such stimuli. In particular, connections to the prefrontal cortex (PFC) allow considerable upward influences on regions involved in higher cognitive and attentional processes (R. Smith et al., 2017).

R. Smith et al. (2017) note attention is reflective of momentary changes in one's assessment of the reliability of sensory input received from different domains. Attention reflects a process of increasing the weight given to synaptic connections deemed to carry high precision signals while decreasing the weight of connections carrying low precision signals. That is, attention will be directed towards stimuli considered to be the most predictive of the organism's current needs to maintain a state of stability and homeostasis. Under high arousal states, such as when faced with a stressor, higher precision estimates tend to be assigned to lower-level, habitual levels of control, while lower weighting is given to higher-level, goal-directed levels (R. Smith et al., 2017). For most individuals faced with an acute stressor, this would mean attending to one's immediate sense of unsafety and striving to integrate incoming sensory information from the body and external world to facilitate adaptive physiological and behavioural changes. In this case, attending to appetitive stimuli would not be supported, as neither higher-level, appetitive goals (i.e., food cravings) nor lower-level hunger (i.e., blood glucose levels) would carry high precision estimates based on the current context (R. Smith et al., 2017). In essence, this accords with the notion that low HRV would generally be expected to decrease attentional bias to food.

The hierarchical basis of neurovisceral integration might also explain why individuals who exhibit higher dietary restraint may differ in their attention to food when encountering a stressor. Though attention shifts to attend to whichever stimuli is deemed to carry the highest precision estimate, as noted above, the expectations and "priors" derived from one's context are influenced by previously learned associations (R. Smith et al., 2017). If one has unintentionally developed a habitual pattern of eating in response to stress, signals at lower levels in the hierarchy suggestive of low HRV may activate priors associated with food consumption. This could have two realistic implications, both of which may theoretically enhance restrained eaters' attention to food. First, this habitual response may automatically dominate action selection (R. Smith et al., 2017). Based on this learned prediction (i.e., low HRV and stress is linked to eating), attentional processes may be unconsciously guided towards food to facilitate this action sequence in the presence of physiological cues of stress (R. Smith et al., 2017). Alternatively, food itself may come to be perceived as a "threat" when restrained eaters experience interoceptive signals of stress. As prior instances of disinhibition have threatened restrained eaters' goal of controlling their intake, food may be inappropriately appraised as salient, despite its lack of adaptive value during stress. As a result, highly restrained individuals may counterproductively become more vigilant for food in an attempt to protect themselves against the "threat" of indulgence. This may ironically enhance their vulnerability to engage in the behaviour they seek to avoid.

Of further relevance to the hierarchical nature of neurovisceral integration, it can be argued that individuals high in dietary restraint regularly give less weighting to signals from their body and routinely disregard these signals as representing lower precision estimates. Restrained individuals are prone to treat physiological signals as unreliable for deciding upon a course of action, such as when they deny their hunger to maintain their allowable caloric range or ignore cravings if a food is deemed off-limits (Herman & Polivy, 1983). It is possible that through habitually ignoring their bodily state, more highly restrained individuals may readily suppress bodily signals in precision-weighting mechanisms, even when those signals communicate vital information about stressors. Thus, in contrast to less restrained individuals whose attentional bias to food would be expected to decrease in response to stress and interoception of low HRV, more highly restrained eaters' attentional bias to food may increase and thereby encourage greater consumption relative to unrestrained eaters. Despite these plausible theoretical links between HRV and attentional bias in dictating consumption, it may also be argued that the question remains as to why the stressor in Study One continued to exert an effect on consumption, and perhaps attention, for individuals even though the acute experience of the stressor had already ended. Here too, theories of HRV may provide insight and inform hypothesized mechanisms.

3.3 The Prolonged Effect of the Laboratory Stressor

After the laboratory stressor, it might be argued that participants' bodily state and external cues in the laboratory should have no longer matched the "prior" for danger or threat. Indeed, Usui and Nishida (2017) found after a mental stress task (i.e., the Stroop Colour-Word task), participants' HRV returned to baseline within 15 min. Though participants proceeded directly to the taste test after the stress task in Study One, there was a brief interim period during which they were "randomized" to the taste test and filled out the Grand Hunger scales. The food was then available for a full 10 min. It could be contended that individuals' HRV may have had sufficient time to recover to a point at which no suppressive effect on intake or attentional bias should have been expected. With respect to exteroceptive cues, it could be claimed that ending the stress task itself should have been enough to signal that a stress-free period had begun, denoting “safety” from threat. The reader is invited to recall, however, that higher levels in the CAN also strive to predict expected future needs (R. Smith et al., 2017). It is postulated those in the stress condition may have been uncertain about their continued “safety” in the laboratory.

Although the stressor had ended, participants remained in the same context in which the stressor was encountered and were aware additional tasks remained to be completed. Prior to the stress task, participants had no reason to anticipate that this so-called “working memory task” would be stressful. Thereafter, no discernable or explicit cue was provided to indicate the forthcoming tasks would not be similarly stressful. As a consequence, those in the stress condition may have experienced apprehension regarding the possibility of subsequent stressful tasks. Uncertainty about further “safety” may have driven continued vigilance for new threats in the laboratory. Thus, perhaps it may have been this uncertainty that was particularly responsible for attenuating the likelihood of attending to appetitive stimuli and, consequently, eating when given access to palatable foods for less restrained eaters. The notion that uncertainty about safety may have continued to suppress attentional bias to food and intake post-stress is founded on the tenets of the generalized unsafety theory of stress (Brosschot et al., 2016, 2017, 2018).

At its core, the generalized unsafety theory of stress hypothesizes the cause of chronic or prolonged stress is a generalized perception of unsafety, which primarily results from automatic, evolutionarily adaptive processes (Brosschot et al., 2016). Neurobiological and evolutionary insights reveal the stress response is the default response of organisms. In normal circumstances, this default response is appropriately inhibited by the PFC when safety is perceived (Brosschot et al., 2018). After birth, young organisms begin to gradually identify signals of safety, a process that continues, though decelerates, into adulthood (Brosschot et al., 2018). The generalized unsafety theory of stress therefore postulates intolerance of uncertainty is not *acquired* during life, but rather, is inherent to all humans (Brosschot et al., 2016). When conceptualized from an evolutionary perspective, it would be adaptive to be cognizant of the potential for threat and err on the side of caution in the absence of obvious safety cues (Brosschot et al., 2018). *Uncertainty* about safety is thus equated to danger. The stress response consequently remains activated in the absence of perceived safety (Brosschot et al., 2016, 2018). Perceived safety is thought to continuously, and relatively unconsciously, evolve via neurovisceral integration of information from one's body and external milieu (Brosschot et al., 2018). Ultimately then, the key element in prolonged stress is one's *uncertainty* regarding continued threat even after a threat has ended.

The generalized unsafety theory of stress theorizes that an inability to recognize safety signals either within one's body or milieu leads objectively neutral situations to be experienced as threatening (Brosschot et al., 2016). Of relevance, individuals' ability to recognize safety and their threshold for inferring threat from uncertainty depends on their environment, learning history, and physical state (Brosschot et al., 2016). As the laboratory environment is likely to represent a relatively novel, unfamiliar situation for most undergraduate students, participants likely would not have had prior learning experiences on which to anchor their expectations about what might occur in this context. That is, participants would not have many prior opportunities to identify signals for safety in such a context. Their threshold for inferring threat from uncertainty may have been low as a result, especially after just experiencing a stressful task in the laboratory.

It is also noteworthy that the generalized unsafety theory of stress further proposes the availability of social safety is the primary signal that enables safety to be perceived for social animals such as humans (Brosschot et al., 2016). When social support is in question, individuals are hence more likely to experience a generalized sense of unsafety. In Study One, those in the stress condition had quite a negative social encounter with the researcher during the MIST. The researcher continuously expressed that participants' performance did not compare to "average" peers and that, given their poor performance, their data would not even be usable. The researcher also communicated with those in the stress condition in a negative tone whilst averting their direct gaze from the participant as they spoke. It might be argued that this social interaction may have created a perception of social rejection and subordination. Elements of this social encounter may thus have contributed to the inability to perceive safety, thereby promoting a generalized sense of unsafety in the laboratory context across the remainder of the experimental protocol.

Pertinent to the current program of research, the generalized unsafety theory of stress articulates generalized unsafety is linked to HRV (Brosschot et al., 2016, 2017, 2018). When safety is in doubt, critical areas of the PFC become hypoactive, thereby removing inhibition of the amygdala and allowing the fight-or-flight response to mobilize and facilitate arousal in anticipation of a threat (Brosschot et al., 2018; Thayer et al., 2012). Brosschot et al. (2016) also note low HRV might be sufficient to cause a lack of recognition of safety, and thus, generalized unsafety by itself. As discussed with respect to the hierarchical nature of neurovisceral integration, low HRV may activate the prior expectation for danger or threat. Indeed, low HRV predicts stress reactions to neutral stimuli (Brosschot et al., 2017; Ruiz-Padial, 2003; Wendt et al., 2015). It is possible then that low HRV may further enhance the likelihood of uncertainty.

Particularly important to the inclusion of attentional bias to food in Study Two, the generalized unsafety theory of stress notes that when safety is unable to be perceived, it would be adaptive to give priority to processing potential threat-related information as well as neutral information in one's environment that could hold the potential to become threatening in the absence of explicit cues for safety (Brosschot et al., 2016). The generalized unsafety theory of stress thus gives further credence to the hypothesis that, in Study One, individuals may have experienced an attenuation of their attentional bias to food and a reduced behavioural inclination towards appetitive stimuli in order to give priority to attending to other details of their experience in the laboratory to cope with their uncertain safety. Study Two thus seeks to assess attentional bias to food after the MIST and investigate whether uncertainty about safety plays a role in the HRV-mediated reduction in consumption. In addition to the aforesaid theoretical links between HRV, uncertainty about safety, and attention to food, a small body of empirical evidence may also support the existence of such associations. This literature will be discussed in Chapter 4.

3.4 A Summary of the Rationale for Study Two

In sum, Study Two will attempt to answer why low HRV attenuated consumption for individuals in the stress condition overall and why this indirect effect was only significant for those low in dietary restraint. It is proposed that, among highly restrained eaters, attentional bias to food may be exacerbated by low HRV. As an enhanced attentional bias towards food would run counter to the attenuation expected of most individuals via low HRV, failing to account for attentional bias as an intermediary link in the mediation model in Study One could have obscured a link between HRV and consumption. That is, without accounting for this potentially differential downstream effect of HRV on attention, it may have attenuated the predictive power of low HRV on consumption for more restrained eaters. For these individuals, attentional bias to food may be more directly linked to consumption. By contrast, the expected shift in attentional bias among less restrained eaters would be in line with the hypothesized impact of low HRV on attentional bias to appetitive stimuli. As a result, attentional bias to food may not necessarily need to be accounted for in the model to significantly predict consumption.

Chapter 4. Does Attentional Bias Towards Food Mediate Stress-Induced Eating Patterns?

4.1 Introduction

A bounty of literature has focused on characterizing patterns of stress-induced eating in the general population (e.g., Araiza & Lobel, 2018; Greeno & Wing, 1994; Macht, 2008), investigating disinhibited eating in response to stress or negative affect among restrained eaters (e.g., Herman & Mack, 1975; Herman & Polivy, 1975, 1980; Stroebe, 2008), and exploring the role of attentional bias to food and its modulation in eliciting food intake (e.g., Kakoschke et al., 2014; Werthmann et al., 2015; Zhang et al., 2018). Theoretical models also explicitly propose a role for attention in evoking disinhibited eating episodes (e.g., Geisler et al., 2016; Heatherton & Baumeister, 1991). Despite theoretical propositions and apparent connections across the aforesaid bodies of literature, a relative dearth of research has examined what occurs to individuals' attentional bias to food when faced with stress and how this may relate to stress-induced patterns of eating among "normal" eaters and restrained eaters.

Attentional bias is defined as one's tendency to preferentially allocate attention towards stimuli deemed to be personally, motivationally, and emotionally relevant (van Ens et al., 2019). Attentional bias to food reflects the degree to which individuals selectively attend to food cues (e.g., images, words, in vivo foods), and it is suggested to index individuals' reactivity to food rewards (Hou et al., 2011). As noted in Chapter 3, theories of HRV implicate a link between attentional bias and stress. Briefly, both the neurovisceral integration model (Thayer & Lane, 2000) and Porges' (1995) polyvagal theory propose stress, and by extension low HRV, causes narrowed attention towards salient environmental cues to respond to the threat. The generalized unsafety theory of stress similarly recognizes that when safety cannot be perceived (e.g., during a stressor when HRV is low), it is adaptive to prioritize attending to potential threat-related cues

(Brosschot et al., 2016). Attention to food might consequently decrease to remain vigilant for imminent threats. Hypothetically, the sequential influence of HRV on attentional bias to food may explain the temporary anorectic response to stress observed in Study One (see Figure 7).

The fact remains, however, that restrained eaters are prone to eat in response to stress (Stroebe, 2008), even in situations where less restrained counterparts reduce their intake (e.g., Heatherton et al., 1991; Herman & Polivy, 1965; Lowe & Kral, 2006; Ward & Mann, 2000). Due to baseline differences in attentional bias to food (Polivy & Herman, 2017) and differential tendencies towards eating when stressed, dietary restraint might moderate the proposed impact of stress and low HRV on attentional bias to food. To further articulate the rationale underlying the aforesaid conjectures, the succeeding sections will be organized as follows. First, existent evidence examining the link between HRV and attention will be discussed to elucidate plausible empirical support for the association between these two proposed mediators (i.e., pathway d_{21} in Figure 7). Evidence linking attentional bias to food and intake will then be reviewed to delineate the feasibility of the pathway between the second mediator, attentional bias to food, and the dependent variable, participant consumption (i.e., pathway b_3 in Figures 7 and 8). Thereafter, the focus will shift to research on attentional bias to food across restrained and unrestrained eaters to corroborate the notion that restraint may moderate the link between the two proposed serial mediators, HRV and attentional bias to food (i.e., pathway d_{22} in Figure 8).

4.1.1 Empirical Links Between HRV and Attentional Bias

No studies to date have directly examined the impact of low HRV on attentional bias to food. Nevertheless, tentative links can be drawn from the literature to indirectly suggest such an association. For example, Oh and Taylor (2013) found after a brisk 15 min walk, females' initial attentional bias to chocolate (i.e., when stimuli was presented for 200 ms) and chocolate craving were significantly lower than after the rest condition. These findings are notable given that bouts of physical exercise elicit a decrease in HRV (Prodel et al., 2017). Moreover, when examining the effect of a sad mood induction on attentional bias to food, Werthmann, Renner, et al. (2014) found those in the sad mood condition exhibited significantly lower initial attentional orienting to food as measured via eye-tracking compared to the neutral mood condition. As depressive mood is also associated with low HRV (Young, Cousins, et al., 2017), it may be reasonable to surmise that reductions in HRV prompted by stress may likewise reduce attentional bias to food.

Insight into the link between HRV and attentional bias to appetitive stimuli more broadly can be derived from Field and Powell's (2007) study exploring the association between stress and attentional bias to alcohol-related cues in healthy social drinkers. Field and Powell (2007) found that a speech anticipation stressor led to a significant attentional bias for alcohol-related cues, though only for those who reported coping motives for drinking (i.e., drinking to cope with negative affect). Though HRV was not measured, similar speech anticipation tasks decrease HRV (Verkuil et al., 2014). These results suggest that, for those with prior associations between appetitive stimuli and stress, attention to such stimuli may be enhanced when HRV is attenuated.

Evidence linking HRV and attentional bias to threat is also relevant to consider. Miskovic and Schmidt (2010) reported low HRV predicted roughly 26% of the variability in attentional bias for angry faces, reflecting a social threat. Further, in a study by Johnsen et al. (2003), dental phobic subjects had a longer reaction time to dental-related words in an emotional Stroop task after watching videos of dental procedures (i.e., a stressor), suggesting difficulty disengaging attention from relevant threat words. Low HRV during the dental videos was also associated with longer reaction times to the threat words (Johnsen et al., 2003). Though attention to threat will not be assessed in this study, the underlying assumption is that low HRV will reduce attentional bias to food as a corollary of enhanced attention to threat. Based on this literature, it seems reasonable to explore whether low HRV alters attention to food. Compared to the paucity of literature on the link between HRV and attentional bias to food, there is robust evidence to show attention to food impacts consumption (i.e., pathway b_3 in Figures 7 and 8), as detailed next.

4.1.2 Attentional Bias Towards Food and Food Intake

Both correlational and experimental studies implicate a link between one's tendency to selectively attend to food stimuli and food intake (Werthmann et al., 2015). Correlational studies that have examined attentional bias to food prior to a taste test have largely demonstrated a significant association, such that greater attentional bias to food is associated with higher intake (Nijs et al., 2010; Overduin et al., 1995; Pollert & Veilleux, 2018; Werthmann, Renner, et al., 2014). This effect even demonstrates specificity, as attentional biases to specific foods (e.g., chocolate) predict their consumption (Werthmann, Roefs, Nederkoorn, & Jansen, 2013). While one correlational study did not find a significant association, the type of food and its manner of presentation may have produced this null finding. Davis Becker et al. (2016) presented mandarin oranges and individually-wrapped chocolates, both of which require "unwrapping." The need to unwrap food can make eating less automatic (van Kleef et al., 2014). Empty wrappers can also enhance self-monitoring and increase perceptions of "public attention" to one's intake, which may alter consumption (Polivy et al., 1986; van Kleef et al., 2014). By contrast, other studies that documented a significant relationship presented food without packaging in large bowls.

Furthermore, in experimental studies that systematically modify biases to attend to food, it has been shown that reducing individuals' attentional bias to certain foods significantly reduces consumption of those foods (Kakoschke et al., 2014; Kemps et al., 2014, 2015; Werthmann, Field, et al., 2014; Zhang et al., 2018). Such studies can better enable inferences about a causal association between attentional bias to food and intake akin to the causal model proposed herein. Although Hardman et al. (2013) did not find an impact of attentional bias modification, it is relevant to note they did not significantly alter individuals' attentional bias to food. Further, Hardman et al. (2013) only presented a single serving of each food with a label denoting whether the food was high- or low-fat. Similar to the effect of wrappers, offering a single serving may have increased the salience of how much individuals ate and made the extent to which one indulged more readily apparent to the experimenter, which might have suppressed intake (Polivy et al., 1986). Labels of high-fat and low-fat could have also made participants think more about their intake and altered their selections (Cioffi et al., 2015), reflecting a contrasting manipulation.

Overall, previous literature indicates that when individuals are trained to alter their attention to food, their intake is consequently modified. On the basis of this evidence, it seems plausible that if attentional bias to food is unintentionally decreased by stress, individuals' intake would decrease as a result. Thus, literature to date seems to corroborate pathway b_3 in Figures 7 and 8. Focus now turns to consider research that can support the notion that dietary restraint may modify the association between stress and attentional bias. First, studies examining the link between attentional biases to food and restraint will be discussed. Subsequent to that, evidence relevant to the role of negative affect or stress and HRV in this association will be explored.

4.1.3 Dietary Restraint and Attentional Bias to Food

Multiple studies reveal those with high dietary restraint exhibit a heightened attentional bias to food words (Francis et al., 1997; Green & Rogers, 1993; Hollitt et al., 2010; Ogden & Greville, 1993; Overduin et al., 1995; Tapper et al., 2008) and images (Hepworth et al., 2010; Meule et al., 2011; Neimeijer et al., 2013; Nijs et al., 2010). While some studies did not find greater attentional bias to food in restrained eaters, methodological choices likely contributed to null effects. For instance, Werthmann, Roefs, Nederkoorn, Mogg, et al. (2013) excluded those with a BMI outside the healthy range. While this was done to minimize the impact of attentional biases to food driven by weight, evidence on attentional bias to food in those who are overweight or obese is equivocal (Werthmann et al., 2015), which calls into question the need to control for weight. Further, as restrained eaters typically have higher BMIs on average (Geisler et al., 2016; Meule, Vögele, & Kübler, 2012; Stroebe, 2008), Werthmann, Roefs, Nederkoorn, Mogg, et al.'s (2013) sample may not have adequately reflected the population of restrained eaters.

Wilson and Wallis (2013) also failed to find greater attentional bias for food words in restrained eaters; however, the authors used a modified Stroop task with questionable validity. In the task, food, ego threat, and neutral words were presented before a sequence of four neutral words. Each target word thus appeared in a sequence of five words. Attentional bias to food was inferred from slower reaction times to words that came after a food word, supposedly suggesting slowed disengagement. Results revealed all participants demonstrated slowed disengagement from the first word to the second and the fastest reaction time for the fifth word, regardless of restraint or target word category. All participants thus exhibited slowed disengagement, even for neutral words (Wilson & Wallis, 2013). Arguably then, the task did not capture meaningful attentional biases. Further, pictorial stimuli offer a more ecologically valid measure of attentional bias to food than words (Veenstra & de Jong, 2010), as images approximate real-world cues and induce gustatory responses in brain regions associated with taste and reward (Freijy et al., 2014).

Though Freijy et al. (2014) also reported null findings, the pictorial stimuli used to reflect high-calorie food were a mound of sugar, a slab of butter, bacon, gummy candy, and doughnuts. While restrained eaters may strive to minimize consumption of sugar or butter, it is unlikely that these pictorial stimuli would promote an appetitive response. Individuals likely would not eat a spoon full of sugar or butter on its own, nor would they likely feel tempted by such foods. As disinhibition is typically found with highly palatable snack foods, such as M&Ms (Strauss et al., 1994), potato chips (e.g., Shapiro & Anderson, 2005), ice cream (Boon et al., 2002), chocolates (e.g., Wallis & Hetherington, 2004), and other high fat and/or high sugar processed foods, it may be most informative when tasks use pictures representative of these types of foods.

It is also important to emphasize that the duration of stimulus presentation may impact the ability to reveal differences between restrained and unrestrained eaters. Although Hummel et al. (2018) found restrained eaters showed a greater bias to attend to low-calorie food images while unrestrained eaters had a heightened bias to high-calorie foods, pictures were shown for 3000 ms. This duration is long enough to allow top-down attentional control, which is enhanced in restrained eaters under normal circumstances (Hotham et al., 2012). Such findings are reasonably in accordance with the construct of dietary restraint itself, which reflects continuous exertion of cognitive control over eating. To truly assess differences between those high and low on restraint, it may be best to explore early attentional processes prior to effortful control. The context may also impact whether an effect is found. For example, Papies et al. (2008) found restrained eaters only demonstrated heightened attentional bias to food after performing a lexical decision task with exposure to food words but not non-food words. Features of one's milieu that enhance the salience of food may thus call out such differences in attention.

Overall, as Polivy and Herman (2017) conclude in their review, it does appear as though restraint is associated with a heightened baseline attentional bias to food. As alluded to above, it is hypothesized that the disparity between highly restrained eaters' attentional biases to food compared to less restrained eaters may be particularly enhanced following a stressor. When situational factors hold the potential to enhance the salience of food, such as the attentional narrowing that accompanies stress and disruption of effortful control via low HRV, restrained eaters' attentional bias to food may increase. In the section that follows, studies examining the impact of experimentally manipulating stress or mood on attentional bias to food are reviewed.

4.1.4 Dietary Restraint, Attentional Bias to Food, and Stress/Negative Affect

A paucity of literature has examined the influence of stress on attentional bias to food (Stojek et al., 2018), much less exploring the moderating role of restraint. Stojek et al. (2018) note such research is sorely needed and may help shed light on the occurrence of binge eating in response to negative emotions. To this author's knowledge, only two studies (i.e., Donofry et al., 2019; Hepworth et al., 2010) have explored how attentional bias to food may be differentially altered in response to a negative mood manipulation depending upon restraint. Interestingly, Hepworth et al. (2010) found that a negative mood induction elicited an enhanced attentional bias to food regardless of restraint, though restrained eating was significantly correlated with a greater attentional bias to food more generally. Donofry et al. (2019) did not find any impact of negative mood induction on attentional bias to food for any individuals. While these findings might seem to contradict the notion that restraint may moderate the impact of stress on attention to food, limitations and differences in methodology negate pre-emptive conclusions.

For example, Donofry et al. (2019) utilized an attentional bias task that has yet to be established as a reliable and valid measurement of food-related attentional bias. Further, both Donofry et al. (2019) and Hepworth et al. (2010) explored the impact of a sad mood induction, rather than a stress induction. Psychological stress is a related, though distinct, construct from mood (Finch et al., 2019). While both stress and sadness may reduce HRV, stress is more likely to elicit parallel activation of the sympathetic nervous system (SNS; Thayer & Brosschot, 2005).

The effect of stress on attentional bias may therefore differ. Studies have yet to be conducted that have examined the impact of stress on attentional biases to food in relation to restraint, indicating a considerable gap in the literature. Nevertheless, tentative links can be drawn from the few studies that have explored attentional biases to food after stress in other populations.

Two published studies have explored the influence of stress on attentional bias to food, one of which (i.e., Newman et al., 2008) examined the moderating role of external eating, a trait eating style referring to the tendency to eat in response to food cues in the environment. Newman et al. (2008) found a significant interaction between external eating and stress on attention to snack food words in a modified Stroop task suggesting that those high on external eating tended to show a greater attentional bias to food in the stress condition. These findings are intriguing as external and restrained eating are associated (van Strien et al., 1986, 2014). Akin to restrained eating, external eating also correlates with enhanced attentional bias to food more generally (Brignell et al., 2009; Hepworth et al., 2010; Hou et al., 2011). These findings could suggest trait eating styles associated with an enhanced proclivity to attend to food may show heightened attentional bias to food in the presence of stress and vice versa for "normal" eaters.

Only one study has documented the influence of stress on attentional bias to food outside of trait eating styles. Schepers and Markus (2017) examined attentional bias to food before and after a stress task. Contrary to predictions in the current study vis-à-vis the impact of stress among all individuals, all subjects exhibited an increased attentional bias for sweet and savoury food images after the stressor (Schepers & Markus, 2017). However, these findings may be impacted by the study's inclusion criteria. As only homozygous carriers of the 5-HTTLPR gene and those in the extreme percentiles of ruminative thinking were included, their sample was not representative of the general population. Conclusions are also limited by their failure to include a non-stressed control condition. Further research is needed to evaluate whether attentional bias to food is altered in response to stress in an unselected sample, as well as to assess the mediating role of HRV and to discern whether restraint moderates this association.

4.1.5 Summary of Gaps in the Literature and Study Two

Despite a considerable body of literature exploring stress-induced eating in the general population, disinhibition in restrained eaters, and the effect of attentional bias to food on intake, a paucity of studies have examined how stress impacts attentional bias to food or whether attentional bias to food is associated with disinhibited eating. Further, no studies have examined how low HRV may impact attention to food. The current study therefore sought to assess whether low HRV prompted by the Montreal Imaging Stress Task (MIST) altered attentional bias to food and, consequently, consumption. Dietary restraint was also included as a moderator to examine whether this association differed among more highly restrained eaters. This study thus offers a novel contribution to the literature on stress and eating and restraint theory by striving to reveal a possible mechanism through which stress may influence food intake. As articulated in Chapter 3, ongoing perceptions of unsafety may also determine whether stress affects attentional bias to food and consumption. In the current study, "safety" was thus manipulated as described in section 4.2.2.6. Given the literature reviewed, the following hypotheses were put forth:

1) There will be a significant serial mediation, such that the MIST stress condition will lead to lower HRV (M_1), which will subsequently lead to lower attentional bias to food (M_2) and finally, lower food consumption for all participants overall (Figure 7);
2) The serial mediation effect will only be significant for those in the stress condition who remain uncertain about the potential for further stress in the laboratory; and,

3) The serial mediation will be moderated by dietary restraint (*W*) between HRV (M_1) and attentional bias to food (M_2) (Figure 8). For those with higher restraint, low HRV will elicit a greater attentional bias to food (i.e., there will be a negative relationship between HRV and attentional bias to food), and vice versa for lower restraint.

4.2 Method

4.2.1 Participants

A total of 156 female participants were recruited from Lakehead University's Thunder Bay campus and the general public in Thunder Bay. Participants were recruited from the Department of Psychology undergraduate participant pool via the Sona Experiment Manager system (see Appendix Q for Sona study description), emails sent to graduate students by the Faculty of Graduate Studies (Appendix R), electronic flyers emailed to all students via the student union (Appendix S), paper flyers and business cards placed around campus, and electronic flyers on social media (i.e., Facebook and Instagram). Participants from Study One were exempt from participating in Study Two. Participants' ages ranged from 17 to 51 years (M = 23.33, SD = 7.16). The majority self-identified as Caucasian (48.1%). The remainder reported South Asian (11.5%), East Asian (10.3%), African-Canadian (9.6%), Aboriginal (5.1%), Hispanic (3.2%), Middle Eastern (2.6%), and "Other" (8.3%) ethnicities (i.e., Southeast Asian, biracial). Two participants did not report ethnicity. Participants' BMIs ranged from 15.62 to 43.16 kg/m^2 (M = 25.39; SD = 5.93). All participants had normal or corrected-to-normal vision.

The same inclusion and preparatory criteria were used as in Study One. The procedure was approved by the Lakehead University Research Ethics Board, and informed consent was obtained prior to commencing the laboratory protocol. As compensation, all participants were given a $10 token honorarium. If participants were recruited via Sona, two and a half bonus points were also awarded to count towards their final grade in an undergraduate psychology course eligible for bonus points. As in Study One, only females were recruited to minimize potential heterogeneity in restraint across the conditions given differences in restraint across males and females (de Witt Huberts et al., 2013).

Of the 156 participants recruited, two were excluded due to an inability to partake in the taste test. Although recruitment materials stated participants must not have dietary restrictions, two individuals revealed restrictions precluding participation when shown allergen information before the taste test. An additional seven participants were removed for answering all attentional assessment questions from the baseline video incorrectly, leaving a sample of 147 participants.

4.2.2 Materials

4.2.2.1 ***Demographics Questionnaire***

The demographics questionnaire (Appendix U) was similar to that used in Study One, with one additional yes or no question appended to ascertain dieting status (i.e., "Are you currently dieting to lose weight?"). This question was included given its relevance for attentional bias to food (Tapper et al., 2008); however, dieting status was unrelated to attentional bias to food in the current study.

4.2.2.2 ***Stress and Depressive Symptomatology***

The same measures from Study One were used to assess stress ratings and depressive symptoms. The Stress Rating Questionnaire (SRQ; Edwards et al., 2006; Appendix E) exhibited good internal consistency at baseline (α = .81) and excellent internal consistency following the first round of the MIST (α = .93), prior to the taste test (α = .92), and after the second MIST (α = .90). The Quick Inventory of Depressive Symptomatology – Self-report ($QIDS\text{-}SR_{16}$; Rush et al., 2003; Appendix O) showed acceptable internal consistency (Cronbach's α = .74).

4.2.2.3 *Height and Weight Measures*

Participants' objective height and weight were measured in the laboratory in the same manner as in Study One. Participants' BMI was computed as detailed in Chapter 2.

4.2.2.4 *Restrained Eating*

As in Study One, restraint was conceptualized using Hagan et al.'s (2017) latent restraint factors. Calorie Counting exhibited good internal consistency (Cronbach's α = .88) and both Preoccupation with Dieting and Weight-Focused Restraint showed excellent internal consistency (Cronbach's α = .91 and α = .93, respectively). Analyses were also conducted with each restraint scale, as described in Study One. The Three-Factor Eating Questionnaire Restraint scale (TFEQ-R; Stunkard & Messick, 1985; Appendix H), Revised Restraint Scale (RS; Herman & Polivy, 1975; Appendix J), and Eating Disorder Examination-Questionnaire Restraint subscale (EDE-Q-R; Fairburn & Bèglin, 1994; Appendix K) demonstrated good internal consistency (Cronbach's α = .89, α = .83, and α = .83, respectively). The Dutch Eating Behaviour Questionnaire Restrained Eating subscale (DEBQ-R; van Strien et al., 1986; Appendix I) and Eating Disorder Inventory-3 Drive for Thinness scale (EDI-3-DT; Garner, 2004; Appendix L) exhibited excellent internal consistency (Cronbach's α = .92 and α = .91, respectively) in the current study.

4.2.2.5 *Hunger*

As hunger may impact attentional bias to food (Mogg et al., 1998; Tapper et al., 2010) and consumption in taste tests (Robinson et al., 2017), participants rated hunger throughout the protocol. Hunger was assessed via a visual analogue scale (Appendix T). Visual analogue scales are typically employed in studies that assess change in hunger over time, as such measures are sensitive in response to fasting and consumption (Lemmens et al., 2011; Ruddock et al., 2018; Tinsley et al., 2018) and show reasonable test-retest reliability across 24 hr fasts at the 16 hr mark (Tinsley et al., 2018). Visual analogue scales have the advantage of being quick to complete, with better score discrimination compared to a Likert-type item (Stubbs et al., 2000). A unipolar scale from "Extremely hungry" to "Not hungry at all" was employed, as this type of hunger scale demonstrated the highest sensitivity and high reliability (Merrill et al., 2002).

To minimize the likelihood that participants deduced a link between the measurement of hunger and experimental tasks, they were required to self-report their hunger prior to each ECG recording, rather than solely before the visual-probe task and taste test. Additional physiological states were also measured via visual analogue scales, including thirst, fatigue, and discomfort. All visual analogue scales were answered in SurveyMonkey™ by dragging a marker with the cursor to the appropriate location on a line anchored by 0 (*not at all*) to 100 (*extremely*).

4.2.2.6 *Perceived Safety*

To ascertain whether the manipulation of perceived safety was effective, additional visual analogue scales were appended to the above physiological variables (Appendix T). Participants were asked to rate how safe, secure, content, and warm they felt from 0 (*not at all*) to 100 (*extremely*). These items were used by Petrocchi et al. (2017) to examine the impact of a mirror self-compassion task based on Gilbert et al.'s scale (2008) to assess safe and content positive affect. Items were averaged to assess "soothing positive affect." Petrocchi et al. (2017) found that greater soothing positive affect was associated with higher HRV.

4.2.3 Experimental Tasks

4.2.3.1 *Montreal Imaging Stress Task (MIST)*

The MIST was used to induce stress presented via Inquisit™ (Version 5.0) software. The MIST was described at length in Chapter 2, where it was shown to significantly reduce HRV and self-confidence in mathematics ability and increase subjective stress for the stress condition.

4.2.3.2 *Perceived Safety Manipulation*

The perceived safety manipulation intended to alter participants' certainty surrounding the likelihood of encountering additional stressors after the stress condition. The MIST stress + certain safety and MIST stress + uncertain safety conditions did not differ during the MIST itself. However, the conditions received different instructions afterwards (Appendix V) both apropos the content and tone. In the certain safety condition, the researcher assured participants they would not have to do any tasks similar to the MIST again and emphasized the remaining tasks would be easy. The researcher used a compassionate, positive tone to further communicate safety and minimize perceptions of threat. In the uncertain safety condition, the researcher stated participants would continue on, vaguely noting they would have to see how they handled the remaining tasks to allow uncertainty regarding further stress. The researcher spoke in a flat, slightly negative tone to amplify the likelihood that participants imbued the ambiguity with ominous meaning. The control condition was simply told they would proceed to the next task.

4.2.3.3 *Visual-Probe Task*

A visual-probe task was used to assess attentional bias to food. The visual-probe task was presented using Inquisit™ (Version 5.0) software. Two categories of pictorial stimuli were shown: 20 food images (e.g., cake), and 20 non-food images (e.g., a hammer). The pictures were selected from the extended *food-pics* database, which contains 896 food images and 315 non-food images under the creative commons license to facilitate standardization of food research (Blechert et al., 2019). Images of high-calorie, processed, and sweet foods were selected, as the heightened incentive salience of such foods would be expected to enhance the likelihood of capturing the attention of most individuals under normal circumstances (Berridge et al., 2010). Moreover, disinhibition in restrained eaters has typically been found with highly palatable, processed snack foods that are often sweet (Boon et al., 2002; Shapiro & Anderson, 2005; Strauss et al., 1994; Wallis & Hetherington, 2004). The food images were further selected by identifying those with the highest valence, arousal, and palatability ratings in the extended *food-pics* normative data (Blechert et al., 2019; Okon-Singer et al., 2013; Samson & Buijzen, 2019).

4.2.3.4 *Taste Test*

Following the visual-probe task, participants were presented with four pre-weighed bowls of the same food items from Study One presented in the same manner for the taste test.

4.2.3.5 *Electrocardiogram (ECG) Recording*

ECG signals were recorded and processed akin to Study One prior to import into Kubios (Version 3.2; Tarvainen et al., 2019) to derive HRV metrics. See Chapter 2 for details. As noted below, similar to Study One, HF-HRV did not significantly decrease from baseline in the stress condition. Hypotheses were thus only examined using RMSSD and the PNS index.

4.2.4 Procedure

Female participants were recruited via the means described in section 4.2.1. Figure 9 displays a visual of the procedural timeline. Upon arrival, participants filled out an eligibility checklist to verify that participatory criteria were met. Participants then read the information letter (Appendix W) outlining what the study entailed and, if they agreed to participate, signed the informed consent form (Appendix X). Participants were then set up for the ECG recordings, as in Study One. The protocol was once again presented via SurveyMonkey™ on a television.

To begin, a 5-min baseline ECG recording was taken as in Study One. After the baseline, participants once again completed questions to assess their attention to the baseline video and the SRQ to report baseline stress (Appendix E) with the appended item to assess mathematics confidence. Participants also completed the visual analogue scales assessing hunger, thirst, fatigue, and discomfort, as well as perceived safety, security, contentedness, and warmth (Appendix T). Participants were told this standard set of ratings would be completed prior to each ECG recording thereafter. Participants were then informed the first task (i.e., the MIST) would begin. Prior to entering the laboratory, participants were randomized to the MIST stress + certain safety, MIST stress + uncertain safety, or control condition via a random number generator. Following the MIST, the second experimental manipulation of perceived safety took place (Appendix V), after which participants filled out the SRQ and visual analogue scales again.

Thereafter, the visual-probe task was presented using Inquisit™ (Version 5.0) under the guise of assessing the relationship between cardiac activity and reaction time. The task was modelled on those previously used to assess attentional bias to food (e.g., Brignell et al., 2009; Hepworth et al., 2010; Hou et al., 2011). Trials consisted of two types of picture pairs across the task: (1) a food (e.g., chocolate cake) versus a non-food picture (e.g., common household object) and (2) a non-food versus a non-food picture. The task began with 12 practice trials, followed by two blocks of 120 test trials. One block presented the images for 100 ms and the other for 500 ms to discern between initial orienting of attention and maintained attention, respectively (Jonker et al., 2019). Blocks were counterbalanced across participants, such that half were presented with the 100 ms block first and the other half saw the 500 ms block first. Of the total 240 trials, 160 were "critical" presenting a food cue with a non-food cue and 80 were filler trials presenting two non-food cues. For the critical trials, each of the 20 food images were shown four times per duration (i.e., left and right as congruent and incongruent trials). The task showed the same picture pairings in the same order for each participant. Each trial presented a fixation cross in the center of the screen for 500 ms, followed by one of the picture pairs for 100 or 500 ms. The pictures were then replaced by an 'X,' the target probe, on either the left or the right side of the screen. Participants were instructed to indicate the location of the target probe as quickly as possible by pressing either the “<” or “>” key to indicate its presentation to the left or right, respectively. Subsequent trials began after participants’ response or, if they did not respond, after 2,000 ms had elapsed. Participants then proceeded to the supposed sensory perception task.

The procedure of the study thereafter was identical Study One through the taste test; the second round of the MIST; completion of the final restraint scales (Appendices H – L), QIDS-SR$_{16}$ (Appendix O), and demographics questionnaire (Appendix U); and height and weight measurement. The total time to complete the laboratory session was approximately 2 hr. Participants were debriefed only after completing data collection via a debriefing email (Appendix Y) in light of concerns detailed in Chapter 2. No participants contacted the research team with concerns about their data upon revelation of the study’s true purpose.

4.3 Results

4.3.1 Data Preparation

Data from psychometric measures were transferred from SurveyMonkey™ into SPSS v.25. Taste test ratings were entered manually from paper-based measures. Data were examined for missing values. Missing values were replaced with prorated scores based on individuals’ mean score on the scale or subscale, as discussed in Chapter 2.

4.3.1.1 *Visual-Probe Data*

As customary, RTs less than 200 ms, over 2000 ms, or more than 3 *SD*s above each participant’s mean RT were considered outliers and excluded accordingly (Hepworth et al., 2010; van Ens et al., 2019). RT data from trials with incorrect responses was also excluded as per convention. Attentional bias to food scores were calculated by subtracting the mean RT to probes replacing food cues (i.e., congruent trials) from the mean RT to probes replacing non-food cues (i.e., incongruent trials). Scores were computed separately for the 100 ms and 500 ms blocks and an overall attentional bias score was computed by averaging scores for both blocks. A positive value indicates a faster RT to probes replacing food images, indicative of attentional bias to food.

4.3.1.2 *ECG Data*

ECG signals were processed using Kubios (Version 3.2) to compute HRV (Tarvainen et al., 2019), as described in Chapter 2. Outliers defined by a z score of ± 3.29 were winsorized by replacement with the next highest nonoutlier value (Field, 2013), as no outliers reflected technological errors. Normality was assessed via $z_{skewness}$, where scores ≥ ± 1.96 were considered significantly skewed (Field, 2013). RMSSD and HF-HRV were positively skewed, and as customary, were transformed using the natural logarithm (ln; Laborde et al., 2017). PNS index was also positively skewed; however, a square root (sqrt) transformation was required to correct the skew. In all analyses, baseline HRV was controlled via its inclusion as a covariate in models.

4.3.2 Data Analysis Strategy

4.3.2.1 *Hypothesis One*

Hayes' (2018a) PROCESS model 6 was utilized to analyze the hypothesis that there would be a serially mediated relationship between the MIST (X) and participant consumption (Y) via HRV (M_1) and attentional bias to food (M_2). As the X variable was multicategorical (i.e., comprised of three groups), a group coding system was required to perform the analyses. A multicategorical variable with g categories can be used as a predictor in a regression model when it is represented with $g – 1$ variables to code the groups. To do so, two variables (i.e., D_1 and D_2) are generated. The pattern of values across D_1 and D_2 represents the group to which a case belongs. PROCESS can automatically implement any coding procedure selected and construct the values of D_1 and D_2 based on the numerical coding of the X variable (Hayes, 2018a). In hypothesis one, Helmert coding enabled a comparison of the two MIST stress conditions (i.e., MIST + certain safety and MIST + uncertain safety) relative to the control condition. Helmert coding computes regression coefficients that quantify the difference between means for one group and all groups ordinally higher on the multicategorical variable (Hayes & Montoya, 2017).

It is important to note that in a mediation with a multicategorical antecedent, the model produces *relative* direct, indirect, and total effects (Hayes & Preacher, 2014). Unlike when the X variable is dichotomous or continuous in nature, there are $g - 1$ paths from X to M_1 and, as a result, $g - 1$ regression coefficients for the a pathway (Hayes, 2018a). Interpretation of these values differs depending on the group coding system utilized. When Helmert coding is used, a_1 quantifies the difference between the unweighted average HRV in the two stress conditions relative to the average HRV in the control condition, and a_2 quantifies the difference in mean HRV between the MIST stress + certain safety and MIST stress + uncertain safety conditions. While there are $g - 1$ coefficients in the X to M_1 pathway, there is only one coefficient between M_1 and M_2 (i.e., d_{21}) and between M_2 and Y (i.e., b_2), as they are both computed holding X constant. Multiplying the a pathways with d_{21} and b_2, two relative indirect effects are generated, $a_1d_{21}b_2$ and $a_2d_{21}b_2$. Each relative indirect effect quantifies the difference in Y between that group and the reference group due to the effect of X on Y via X's effect on M_1 (Hayes, 2018a). As $a_2d_{21}b_2$ (i.e., the difference between the MIST stress + certain safety versus MIST stress + uncertain safety conditions) was not of interest for hypothesis one, it is not reported below.

4.3.2.2 *Hypothesis Two*

Hayes' (2018a) PROCESS macro model 6 with indicator coding was utilized to analyze the hypothesis that the aforesaid indirect effect would only be significant in the uncertain safety condition. The indirect effect can differ depending on the reference group, and thus the coding scheme, employed (Hayes & Preacher, 2014). Indicator coding represents each group of *X* with *g* – 1 variables which are then set to either zero or one. The control condition was used as the reference group to which the two MIST stress conditions were compared. For these analyses, two relative indirect effects are reported whereby $a_1d_{21}b_2$ reflects the indirect effect of the MIST stress + certain safety condition relative to the control condition and $a_2d_{21}b_2$ reflects the indirect effect of the MIST stress + uncertain safety condition relative to the control condition.

4.3.2.3 *Hypothesis Three*

Hayes' (2018a) PROCESS model 91 with indicator coding was utilized to examine whether the indirect effect of the MIST stress condition (*X*) on consumption (*Y*) through HRV (M_1) and attentional bias to food (M_2) was moderated in the pathway between M_1 and M_2 by restraint (*W*). The indices of moderated serial mediation ($a_1d_{22}b_2$, $a_2d_{22}b_2$) quantify the linear association between the indirect effect and putative moderator (Hayes, 2015) and indicate whether the mechanism's size or strength is increased or decreased in concert with restraint.

4.3.2.4 *Statistical Inferences From PROCESS*

As noted in Chapter 2, PROCESS uses an OLS framework to estimate unstandardized regression coefficients (*b*), standard errors (*SE*), direct and indirect effects, and indices of serial mediation and moderated serial mediation. When the 95% CI does not include zero, it reflects statistical significance (Hayes & Rockwood, 2017). If the moderated serial mediation in hypothesis three was significant, it was planned to probe the model by conducting an inferential test of the conditional indirect effect at the 16^{th}, 50^{th}, and 84^{th} percentiles of restraint.

4.3.2.5 *Covariates*

Participants' average reported liking of the food and self-reported hunger prior to the taste test were significantly associated with the amount of food they consumed during the taste test ($r = .34$, $p < .001$ and $r = .18$, $p < .05$, respectively). As such, both liking and hunger were included as covariates in each model. Although age was also significantly associated with the amount of food consumed, age exhibited a significant correlation with average food liking. Upon controlling for liking, the correlation between age and consumption was no longer significant. Thus, to retain power and keep the model as parsimonious as possible, age was not included.

Studies show age and BMI may influence HRV (Sarlon et al., 2018). Age and BMI were only associated with HF-HRV. As HF-HRV was not used to analyze the models, neither variable was included. In line with evidence that oral contraceptive use may impact HRV (Laborde et al., 2017; Teixeira et al., 2015), oral contraceptive use was significantly associated with ln RMSSD, $r = -.18$, $p < .05$, and sqrt PNS index, $r = .22$, $p < .01$, during the MIST. Oral contraceptive status was thus included as a covariate in relevant analyses. QIDS-SR_{16} scores were also significantly associated with sqrt PNS index, $r = -.19$, $p < .05$, and included as a covariate in relevant models.

Self-reported days since the onset of last menses was significantly associated with overall attentional bias to food scores, $r = .20$, $p < .05$, and attentional bias to food scores for the 500 ms block, $r = .26$, $p < .01$, which may align with evidence of differential patterns of brain activation upon viewing visual food cues depending on females' menstrual cycle phase (Frank et al., 2010). As such, days since the onset of last menses was included as a covariate in appropriate analyses.

4.3.2.6 *Parametric Assumptions*

Prior to analyses, data were assessed for violations of parametric assumptions. As noted in Chapter 2, mediation and moderated mediation are based on OLS regression and must thus fulfill the assumptions of homoscedasticity, normality, additivity and linearity, and independence of errors. There was no evidence of a systematic relationship between errors and predictions when inspecting the scatterplots, and it was thus concluded the assumptions of homoscedasticity and linearity were met (Field, 2013). Heteroscedasticity-consistent SE estimates were also utilized in PROCESS (Hayes & Cai, 2007). With respect to normality, all variables were examined for outliers, defined as a *z* score of ± 3.29 (Field, 2013). Outliers were replaced with the next highest value that did not meet outlier criteria (Field, 2013). Continuous variables were also tested for normality using $z_{skewness}$. Variables with a $z_{skewness} \geq \pm 1.96$ were considered significantly skewed (Field, 2013) and transformed as necessary, as discussed below.

4.3.3 Descriptive Statistics

Descriptive statistics for key psychometric, physiological, and demographic variables are presented in Table 8. Participants consumed an average of 58.18 g (*SD* = 30.84) of food during the taste test. Participants' consumption; Weight-Focused Restraint, Preoccupation with Dieting, EDE-Q-R, and EDI-3-DT scores; and overall attentional bias score were significantly positively skewed and transformed via square root transformations, which corrected the skew. Soothing positive affect was negatively skewed. As such, scores had to be reversed prior to transformation by subtracting each score from the highest score (Field, 2013). A square root transformation was then applied, which normalized the skew. Examining covariates, hunger before the taste test and days since last onset of menses were positively skewed and square root transformed to correct it.

4.3.4 Manipulation Checks

4.3.4.1 *MIST Stressor*

A 2-between (condition [MIST stress vs. MIST control]) × 2-within (block [baseline vs. MIST]) mixed factorial ANOVA was conducted to ensure that the stress condition significantly reduced HRV across each metric. The MIST stress + certain safety and MIST stress + uncertain safety conditions were collapsed, as the HRV recording during the MIST occurred prior to the perceived safety manipulation. It was expected there would be a significant interaction between condition and block, such that individuals in the stress condition would exhibit a significant decrease in HRV, whereas HRV would not significantly change in the control condition. For ln RMSSD, there was a significant block × condition interaction, $F(1, 145) = 9.37$, $p < .01$, with a medium effect size ($\eta_p^2 = 0.06$). By contrast, the interaction was not significant for ln HF-HRV, $F(1, 145) = 2.30$, $p = 0.13$. Nevertheless, the block × condition interaction, $F(1, 145) = 26.47$, $p < .001$, was also significant for sqrt PNS index, with a large effect size ($\eta_p^2 = 0.15$).

Mixed factorial ANOVAs were followed up by paired samples *t*-tests within each MIST condition to verify the expected pattern of HRV from baseline to the MIST. As expected, ln RMSSD did not significantly differ between blocks in the control condition, $t(49) = 1.00$, $p = .32$, while the stress condition exhibited a significant reduction in ln RMSSD, $t(96) = 3.84$, $p < .001$. There was no significant difference for ln HF-HRV in either the control condition, $t(49) = 0.40$, $p = .69$, or the stress condition, $t(96) = 1.97$, $p = .05$. Confirming results for ln RMSSD, there was a nonsignificant difference across blocks on sqrt PNS index for the control condition, $t(49) = 1.24$, $p = .22$, and a significant decrease in the stress condition, $t(96) = 8.20$, $p < .001$.

Finally, to ensure HRV during the MIST significantly differed across conditions, ANCOVAs were conducted controlling for baseline HRV. The stress condition exhibited significantly lower ln RMSSD than the control condition, $F(1, 144) = 12.57$, $p < .01$, with a medium-to-large effect size ($\eta_p^2 = 0.08$). The same pattern of differences emerged for ln HF-HRV, $F(1, 144) = 4.66$, $p < .05$, $\eta_p^2 = 0.03$, with a small effect size, and sqrt PNS index, $F(1, 144) = 31.65$, $p < .001$, $\eta_p^2 = 0.18$, with a large effect size. It was concluded that the MIST performed as expected for ln RMSSD and sqrt PNS index, as exhibited by a significant reduction in HRV. HF-HRV was not used in analyses given the null decrease from baseline to the MIST.

4.3.4.2 *Perceived Safety*

To examine whether the perceived safety manipulation affected subjective safety, a 3-between (condition [MIST stress + certain safety vs. MIST stress + uncertain safety vs. MIST control]) × 2-within (block [baseline vs. post-MIST certainty manipulation]) mixed factorial ANOVA was conducted on transformed soothing positive affect scores. There was a significant block × condition interaction, $F(2, 144) = 16.67$, $p < .001$, $\eta_p^2 = 0.19$, with a large effect size, whereby both the MIST stress + certain safety and MIST stress + uncertain safety conditions elicited a stronger decrease in soothing positive affect. An ANCOVA was then conducted to examine whether the conditions differed when controlling for baseline. It was predicted those in the MIST stress + uncertain safety condition would exhibit significantly lower scores compared to the MIST stress + certain safety and control conditions. By contrast, it was anticipated the MIST stress + certain safety condition would not significantly differ from the control condition. There was a significant effect of condition on soothing positive affect, $F(2, 143) = 20.44$, $p < .001$, $\eta_p^2 = 0.22$. However, planned contrasts demonstrated both the MIST stress + certain safety, $F(1, 143) = 26.50$, $p < .001$, $\eta_p^2 = 0.16$, and uncertain safety condition, $F(1, 143) = 33.97$, $p < .001$, $\eta_p^2 = 0.19$, reported significantly lower soothing positive affect than controls, and the two stress conditions did not differ, $F(1, 143) = 0.44$, $p = 0.51$, $\eta_p^2 = 0.003$.

An ANCOVA was also conducted to compare soothing positive affect scores just after the visual-probe task to examine whether there was a delayed effect. The ANCOVA once again indicated a significant effect of condition, $F(2, 143) = 6.21$, $p < .01$, $\eta_p^2 = 0.08$. Upon examining planned contrasts, however, both the MIST stress + certain safety, $F(1, 143) = 7.24$, $p < .01$, $\eta_p^2 = 0.05$, and uncertain safety condition, $F(1, 143) = 10.90$, $p < .01$, $\eta_p^2 = 0.07$, had significantly lower soothing positive affect than the control condition and the two stress conditions still did not significantly differ from one another, $F(1, 143) = 0.36$, $p = .55$, $\eta_p^2 = 0.003$.

4.3.4.3 ***Subjective Stress and Math Confidence***

Two separate 3-between (condition [MIST stress + certain safety vs. MIST stress + uncertain safety vs. MIST control]) × 2-within (phase [baseline vs. post perceived safety manipulation]) mixed factorial ANOVAs were conducted to examine the impact of the MIST on subjective stress and self-reported confidence in mathematical ability. These analyses were undertaken with the stress conditions separated as these ratings occurred after the perceived safety manipulation. There was a significant block × condition interaction for subjective stress, $F(2, 144) = 38.34$, $p < .001$, with a large effect size ($\eta_p^2 = 0.35$) and for math confidence, $F(2, 144) = 11.25$, $p < .001$, with a large effect size ($\eta_p^2 = 0.14$). Both stress conditions had a greater increase in stress and a greater decrease in math confidence relative to the control condition, with the MIST stress + uncertain safety condition showing the highest stress and lowest confidence.

In the ANCOVA examining self-reported math confidence just following the MIST, there was a significant effect of condition, $F(2, 143) = 12.07$, $p < .001$, $\eta_p^2 = 0.14$. Planned contrasts showed that both the MIST stress + certain safety, $F(1, 143) = 17.81$, $p < .001$, $\eta_p^2 = 0.11$, and the MIST stress + uncertain safety condition, $F(1, 143) = 18.14$, $p < .001$, $\eta_p^2 = 0.11$, exhibited significantly lower confidence in their mathematical abilities compared to the control condition; however, the two stress conditions did not differ from one another, $F(1, 143) = 0.002$, $p = .97$, $\eta_p^2 = 0.00$. Another ANCOVA was conducted to examine self-reported math confidence prior to the taste test, which revealed a significant effect of condition, $F(1, 143) = 11.65$, $p < .001$, $\eta_p^2 = 0.14$. The pattern of the planned contrasts was similar, such that both stress conditions exhibited significantly lower math confidence; however, the stress conditions did not differ. Thus, the perceived safety manipulation did not have a differential impact on confidence levels over time.

The ANCOVA examining subjective stress after the MIST and perceived safety manipulation revealed a significant effect of condition, $F(2, 143) = 41.66$, $p < .001$, $\eta_p^2 = 0.37$. Planned contrasts revealed both the MIST stress + certain safety, $F(1, 143) = 51.69$, $p < .001$, $\eta_p^2 = 0.27$, and the MIST stress + uncertain safety, $F(1, 143) = 70.72$, $p < .001$, $\eta_p^2 = 0.33$, reported significantly higher subjective stress than the control condition. However, the two stress conditions did not significantly differ, $F(1, 143) = 1.34$, $p = 0.25$, $\eta_p^2 = 0.01$. It was once again reasoned that if the perceived safety manipulation was effective, there should have been a continued effect on individuals' stress for those in the MIST stress + uncertain safety condition, which might have been delayed. Thus, a second ANCOVA was conducted for subjective stress reported by participants after the visual-probe task and just prior to the taste test.

There was a significant effect of condition on subjective stress prior to the taste test, $F(1, 143) = 12.36$, $p < .001$, $\eta_p^2 = 0.15$, with a large effect size. Planned contrasts revealed that both the MIST stress + certain safety, $F(1, 143) = 7.14$, $p < .01$, $\eta_p^2 = 0.05$, and MIST stress + uncertain safety condition, $F(1, 143) = 24.64$, $p < .001$, $\eta_p^2 = 0.15$, exhibited significantly higher stress than the control condition. However, at this delayed time, the effect size was larger for the MIST stress + uncertain safety condition. Moreover, the contrast between the stress conditions revealed that the MIST stress + uncertain safety condition exhibited significantly higher stress, $F(1, 143) = 5.01$, $p < .05$, $\eta_p^2 = 0.03$. This suggests that participants in the MIST stress + uncertain safety condition continued to feel more stressed even after the stressor ended, suggesting the perceived safety manipulation did prolong stress in the laboratory to some extent.

4.3.5 Group Comparisons

Univariate ANOVAs and chi-square tests were conducted to compare the conditions on all pertinent psychometric and demographic variables to explore whether there were any unintended differences. The conditions did not significantly differ on age, BMI, depressive symptoms, use of oral contraceptives, ethnicity, marital status, dieting status, or days since last onset of menses. Further, there were no significant differences on the latent restraint factors or conventional restraint scales. Finally, participants did not differ with respect to baseline hunger or HRV across any metrics. It was concluded participants had been effectively randomized.

4.3.6 Simple Mediation Model

As in Study One, the data were first subjected to Hayes' (2018a) PROCESS macro model 4 to examine whether HRV mediated the relationship between the MIST and participants' consumption. Helmert coding was used to compare the two MIST stress conditions relative to the control condition. Contrary to Study One, there was no evidence of a significant mediation via ln RMSSD in the sample as a whole, $a_1b = -.099$, $SE = .102$, 95% CI [-.329, .068]. Results were similar using the sqrt PNS index, $a_1b = -.192$, $SE = .157$, 95% CI [-.520, .096].

4.3.7 Hypothesis One

Hypothesis one examined whether there was a serially mediated relationship between the MIST (X) and participant consumption (Y) via HRV (M_1) and attentional bias to food (M_2). The index of serial mediation was not significant for the 100 ms block, 500 ms block, or overall attentional bias score employing either ln RMSSD or sqrt PNS index as M_1 (see Table 9 for the indices of serial mediation). Of interest, although the path between HRV and attentional bias was not significant for the 100 ms block, $d_{21} = -5.009$, $p = .11$; 500 ms block, $d_{21} = -1.856$, $p = .58$; or overall attentional bias score, $d_{21} = -0.400$, $p = .07$, the negative coefficient suggests that as HRV decreased, attentional bias to food tended to increase.

4.3.8 Hypothesis Two

Hypothesis two analyzed whether the aforesaid serial mediation of the relationship between the MIST (X) and participant consumption (Y) via HRV (M_1) and attentional bias to food (M_2) was only significant for those in the MIST stress + uncertain safety condition. The index of serial mediation was not significant for any of the attentional bias scores for either the MIST stress + certain safety condition or the MIST stress + uncertain safety condition relative to the control condition when using either ln RMSSD or sqrt PNS index as M_1 (see Table 10).

4.3.9 Hypothesis Three

Hypothesis three assessed whether the indirect effect of the MIST (X) on consumption (Y) through HRV (M_1) and attentional bias to food (M_2) was moderated in the pathway between the mediators by dietary restraint (W). Hypothesis three was not supported for the latent restraint factors or restraint scales using any attentional bias score across either ln RMSSD or sqrt PNS index for either relative indirect effect. Table 11 contains the indices of moderated serial mediation for the latent restraint factors.

4.3.10 Summary

To sum, there was no evidence that HRV (M_1) and attentional bias to food (M_2) serially mediated the relationship between the MIST and participants' consumption or that restraint moderated the serial mediation. In contrast to Study One, this study also did not find evidence of a significant simple mediation via HRV. Upon post hoc theorizing, it was reasoned that the longer delay between the MIST and taste test in the current study due to the introduction of the 10-min visual-probe task may have minimized the predictive power of HRV due to its temporal kinetics, as discussed in Chapter 1 (e.g., Appelhans & Luecken, 2006).

4.3.10.1 *Exploratory Hypotheses*

It was hypothesized that by the time participants reached the taste test, group differences in HRV may have dissipated. However, the MIST stress + uncertain safety condition who reported greater ongoing stress may have shown higher SNS activity than the control or MIST stress + certain safety conditions. As ECG was recorded during the visual-probe, the conditions' HRV and SNS activity could be compared pre-taste test.

Although attentional bias to food did not sequentially mediate the relationship between stress and consumption, reliability analyses revealed that the attentional bias to food scores exhibited unacceptable internal reliability (Cronbach's α = -.10 – .10). It was thus conjectured that hunger, another variable reflecting motivation towards food and correlated with attentional bias to food (Mogg et al., 1998; Tapper et al., 2010), might play a role instead. In accordance with proposals that unrestrained eaters reduce their intake after physical threats due to presumed SNS activation (Heatherton et al., 1991), high SNS activity could reduce hunger and thus intake. As it was expected that those in the MIST stress + uncertain safety condition would exhibit significantly higher SNS activation, it was also predicted the proposed serial mediation via SNS activation (M_1) and hunger (M_2) would only be significant in this condition relative to the control condition. Further, as those with higher dietary restraint theoretically rely less on physiological cues to dictate consumption (Herman et al., 1987), it was hypothesized restraint would moderate the pathway between hunger (M_2) and consumption (Y; see Figure 10).

4.3.11 Exploratory Analyses

4.3.11.1 *Data Preparation*

In addition to HRV metrics, Kubios (Version 3.2) automatically generates a SNS index comprised of mean HR, the square root of Baevsky's stress index, and the Poincaré plot index SD2 in normalized units (n.u.), where values are compared to normal resting values (Tarvainen et al., 2019). No outliers were identified on the SNS index during the visual-probe. SNS index was positively skewed and subjected to a square root transformation, which corrected the skew.

4.3.11.2 *Exploratory Analytic Strategy*

ANCOVAs were conducted to examine whether conditions differed on HRV and SNS activity during the visual-probe. Hayes' (2018a) PROCESS macro model 87 with indicator coding was subsequently used to examine the hypothesis that the effect of the MIST (X) on participant consumption (Y) would be mediated by SNS index during the visual-probe (M_1) and pre-taste test hunger (M_2), with restraint moderating the path between hunger and consumption. Model 87 generates indices of moderated serial mediation ($a_1d_{21}b_3$, $a_2d_{21}b_3$). The model was probed by examining the conditional indirect effects at the 16th, 50th, and 84th percentiles of restraint. Baseline SNS index, baseline hunger, and average food liking were included as covariates in addition to pre-taste test thirst due to its association with hunger, $r = .45$, $p < .001$.

4.3.11.3 *Exploratory Results*

4.3.11.3.1 ANCOVAs. Examining ln RMSSD during the visual-probe, there was a nonsignificant effect of condition, $F(2, 143) = 1.01$, $p = .37$, $\eta_p^2 = 0.01$. The effect of condition was marginally significant for sqrt SNS index, $F(2, 143) = 2.93$, $p = .06$, $\eta_p^2 = 0.04$. Planned contrasts indicated that although the stress conditions did not significantly differ, $F(1, 143) = 0.43$, $p = .52$, $\eta_p^2 = 0.003$, the MIST stress + uncertain safety condition exhibited significantly greater SNS activity than the control condition, $F(1, 143) = 5.51$, $p < .05$, $\eta_p^2 = 0.04$, whereas the MIST stress + certain safety condition did not, $F(1, 143) = 2.75$, $p = .10$, $\eta_p^2 = 0.02$.

4.3.11.3.2 Moderated Serial Mediation. Results revealed a significant index of moderated serial mediation for Preoccupation with Dieting, $a_2d_{21}b_3 = .027$, $SE = .017$, 95% CI [.002, .067], and Weight-Focused Restraint, $a_2d_{21}b_3 = .029$, $SE = .019$, 95% CI [.001, .074], but only in the MIST stress + uncertain safety condition relative to the control condition. On the conventional restraint scales, the model was likewise significant for the EDE-Q-R, RS, TFEQ-R, and DEBQ-R. Table 12 displays the relative indices of moderated serial mediation.

As expected, the MIST (X) significantly increased sqrt SNS index (M_1) for the MIST stress + uncertain safety condition relative to the control condition, $a_2 = .097$, $p < .05$, but not for the MIST stress + certain safety condition, $a_1 = .062$, $p = .15$. The significant negative link between sqrt SNS index (M_1) and pre-taste test hunger (M_2), $d_{21} = -2.832$, $p < .001$, indicates that higher SNS activation led to lower hunger, and the positive coefficient between hunger (M_2) and consumption (Y), $b_1 = .355$, $p < .05$, means lower hunger led to lower intake, as predicted. The significant negative coefficient for $M_2 \times W$ for Preoccupation with Dieting, $b_3 = -.097$, $p < .01$, reflects that for two cases differing by a unit on hunger (M_2), consumption (Y) increased by 0.097 units as Preoccupation with Dieting (W) increased by one unit. Weight-Focused Restraint showed a similar pattern. Ergo, as restraint increased, lower hunger led to greater intake.

The conditional indirect effects at the 16th, 50th, and 84th percentiles of Preoccupation with Dieting and Weight-Focused Restraint are shown in Table 13 and represented graphically in Figure 11. Though the conditional indirect effects were not significant, it does not imply lack of moderation (Hayes, 2018a). If M_2's effect on Y is significantly moderated by W, as indicated by significant indices of moderated serial mediation, M_2 necessarily impacts Y at some point in W's distribution (Hayes, 2018a). The choice of values of the moderator used to probe an interaction in the pick-a-point approach is somewhat arbitrary and can impact the results (Hayes, 2018a).

The Johnson-Neyman technique offers an alternative that algebraically derives the value or values of the moderator where the conditional indirect effect transitions between significance and nonsignificance, thereby eliminating the need to select values of the moderator (Hayes, 2018a). The conditional indirect effect was significant among those with a sqrt Preoccupation with Dieting score < 1.296, reflecting the lower 7.48% of the sample on this metric. The effect was positive among those with lower scores; however, as Preoccupation with Dieting increased, the effect became negative suggesting reduced hunger led to greater consumption. The conditional indirect effect was significant among those with a sqrt Weight-Focused Restraint score < 3.676, reflecting the lower 8.84% of the sample with a similar pattern of results.

4.4 Discussion

The current study sought to explore whether attentional bias to food plays a causal role in sequence with low HRV in eliciting stress-induced attenuations in eating. It was anticipated that low HRV would decrease attentional bias to food and thereby reduce consumption. It was further hypothesized that individuals with higher dietary restraint would enhance their attention to food while less restrained individuals would decrease their attention to food as a result of low HRV. The aim of this research was to advance current understanding of differential patterns of eating across restrained and unrestrained eaters when faced with stress and illuminate the mechanisms behind restrained eaters' tendency towards stress-induced eating. In an attempt to delineate the circumstances under which stress-induced alterations in eating occur, it was additionally investigated how perceptions of unsafety after a stressor might influence the emergence of the aforesaid relationship. Though none of the hypotheses put forward were supported, exploratory analyses revealed intriguing findings that may help to solidify understanding of restrained eaters' patterns of eating and corroborate previously unsupported conjectures about their eating style.

4.4.1 Lack of Serial Mediation via Attentional Bias to Food

Contrary to predictions, there was no evidence of a serial mediation. Although the stress condition did lead to lower HRV (M_1), low HRV did not lead to lower attentional bias to food (M_2) or lower food consumption for all participants overall. Further contrary to hypotheses, the proposed serial mediation was not significant for either the MIST stress + certain safety or MIST stress + uncertain safety conditions relative to the control condition. In fact, although the d_{21} coefficient representing the path between HRV and attentional bias to food was not significant for any attentional bias scores, the coefficient was negative. The negative coefficient suggests that as HRV decreased, attentional bias to food tended to increase, rather than decrease. It is possible that low HRV may enhance attention to all biologically-relevant stimuli during stress. Indeed, food is a relevant stimulus for all humans due to its survival value (Hollitt et al., 2010) and individuals generally tend to show preferential processing of survival-relevant stimuli (Sakaki et al., 2012). One can also imagine circumstances in the evolutionary past where the threat might have been another individual or group attempting to steal one's food resources. Nonetheless, this apparent trend must not be overstated given its lack of significance and limitations associated with the visual-probe task.

Although the dot probe or visual-probe task paradigm (MacLeod et al., 1986) is one the most frequently used tasks to measure attentional bias to food, and may be preferable to tasks such as the emotional Stroop task (Hepworth et al., 2010; MacLeod et al., 2019; McNally, 2019; Werthmann et al., 2015), criticisms have been levied against this paradigm. In particular, the test-retest reliability and internal reliability for scores from the visual-probe task are poor, at least when examining attention towards threat- and addiction-related stimuli (Rodebaugh et al., 2016; Waechter et al., 2014). Nevertheless, De Schryver et al. (2018) argued the visual-probe task is an overarching paradigm and changing the stimuli creates a new test for which the psychometric properties must be evaluated. van Ens et al. (2019) thus asserted attentional bias to food scores may not exhibit the same difficulty with low reliability. Conducting the first study to examine the visual-probe task's reliability to assess attentional bias to food, van Ens et al. (2019) found adequate internal reliability values (α = .62 - .79) that exceeded those found in other literatures (e.g., Ataya et al., 2012). In light of van Ens et al.'s (2019) study, it was deemed acceptable to use the visual-probe task to assess attentional bias to food in this study. However, scores in the current study had highly unacceptable reliabilities. It is important to acknowledge that van Ens et al. (2019) used a stimuli duration of 3000 ms, which is considerably longer than the duration used in other studies of attentional bias to food (Hepworth et al., 2010; Nijs et al., 2010) and in the current study. De Schryver et al. (2018) indeed noted changing any task parameter, including the stimulus duration, can alter a task's reliability. Given low reliability, results herein may be confounded by measurement error. Low reliability sets an upper limit on the observed links between variables and can reduce statistical power (Hardman et al., 2021). As a result, the current study cannot definitively conclude whether low HRV serially impacts attentional bias to food and stress-induced consumption due to the limitations of the attentional bias measurement.

4.4.4.1 *Lack of Moderated Serial Mediation*

In light of the aforementioned limitations of the visual-probe task and the low reliability of the attentional bias to food scores, it is unsurprising that the proposed serial mediation was also not moderated by restraint in the path between HRV (M_1) and attentional bias to food (M_2). No previous studies have examined the relationship between HRV and attentional bias to food or the moderating role of restraint. However, it is interesting to consider a study testing the process model of ego depletion by Pollert and Veilleux (2018) that explored whether self-control exertion impacts attentional bias to food and subsequent intake in a taste test. Though they did not intend to capture disinhibition, restrained and unrestrained eaters were recruited to "control for the motivational component within the process model" (Pollert & Veilleux, 2018; p. 25). Results revealed no significant difference in attentional bias or food consumption across the self-control exertion and control conditions and no difference between restraint groups in attentional bias to food after self-control exertion (Pollert & Veilleux, 2018).

Despite the lack of moderation by restraint, Pollert and Veilleux's (2018) visual-probe task included three types of trials: reward (e.g., chips, people eating) versus neutral images, self-control (e.g., exercise equipment, person pushing away cake) versus neutral images, and reward versus self-control images. Including self-control images related to dieting and exercising may have primed cognitions related to weight control. Priming a diet-related mindset can significantly reduce attention for high-calorie food (Werthmann et al., 2016) and food consumption (Papies & Hamstra, 2010) in highly restrained eaters. It is therefore unclear how attentional bias to food may be impacted in restrained eaters post-stress or self-control exertion without strong cues for self-control present. A stressful task such as the MIST may also differ from the task used by Pollert and Veilleux (2018), which involved crossing out the letter 'e' on a page of text if it was not adjacent to a vowel or separated from a vowel by one character. Thus, the true effect or lack thereof of dietary restraint in moderating an association between low HRV and attentional bias to food in the prediction of one's food intake remains unknown and is worthy of future exploration.

4.4.2 Nonsignificant Simple Mediation

In addition to the visual probe task's abysmal reliability, another reason why the hypothesized serial mediation models may not have materialized is that, unlike Study One, there was no evidence of an indirect effect between the laboratory stressor and participants' consumption via HRV despite significant differences across conditions in HRV and food intake. Reflecting on the current study's design, a substantially greater time delay was introduced between the stress task and taste test due to the inclusion of the visual-probe task. This delay was a critical oversight given the temporal kinetics of the PNS (Appelhans & Luecken, 2006), as described in Chapter 1. It is additionally vital to highlight that although the SNS and PNS have a dynamic and antagonistic relationship, their relationship is complex. Their respective activity does not operate in a zero sum relationship as opposite ends of one autonomic spectrum (Shaffer & Ginsberg, 2017). For example, HR recovery after aerobic exercise involves reactivation of the PNS while SNS activity stays elevated (Shaffer & Ginsberg, 2017).

By the end of the 10 min visual-probe task, differences in HRV could have attenuated due to PNS reactivation. Nonetheless, as the MIST stress + uncertain safety condition continued to exhibit significantly higher subjective stress after the visual-probe task than the control and MIST stress + certain safety conditions, they may have been experiencing ongoing SNS activation. As predicted, there was no significant difference across conditions in HRV during the visual-probe task. Though the main effect of condition was only marginally significant for sqrt SNS index ($p = .06$), planned contrasts revealed only the MIST stress + uncertain safety condition exhibited significantly greater SNS activation than controls with a small-to-medium effect size. While not reported, it is notable that during the MIST, both stress conditions showed significantly greater SNS activity than the control condition. Ergo, results corroborated the notion that differences in HRV attenuated while SNS activation persisted among those who remained uncertain about their continued safety from stress after the stressor. In essence, PNS withdrawal was superseded by SNS activation prior to the taste test. It was thus deemed worthwhile to examine whether SNS activity contributed to differences in consumption.

4.4.2.1 *Serial Mediation via SNS and Hunger*

The exploratory moderated serial mediation proposed that prolonged SNS activity would attenuate hunger and thereby reduce participants' consumption. Hunger was examined in place of attentional bias to food as another variable capable of indexing motivation towards food given the low reliability of the attentional bias to food scores and its association with attentional bias to food (Mogg et al., 1998; Tapper et al., 2010). It was further anticipated that this relationship would be moderated by dietary restraint, such that the reduction in hunger may be dissociated from consumption in those with higher restraint. As predicted, the relative index of moderated serial mediation was only significant for the MIST stress + uncertain safety condition.

Based on the generalized unsafety theory of stress (Brosschot et al., 2016), it was conjectured that only individuals who remained uncertain about their ongoing safety in the laboratory after the stressor would be vulnerable to exhibit alterations in eating. Although those in the MIST stress + uncertain safety condition did not report significantly greater subjectively perceived lack of safety, as quantified via soothing positive affect (i.e., how safe, secure, content, and warm they felt), this condition exhibited significantly elevated subjective stress relative to both the control and MIST stress + certain safety conditions after the visual-probe task, just prior to the taste test. Furthermore, as noted above, sqrt SNS index during the visual-probe task was only significantly higher than the control condition for the MIST stress + uncertain safety condition. Thus, the perceived safety manipulation was effective in encouraging continued stress in the laboratory on a physiological and psychological level even after time had elapsed.

The fact that the moderated serial mediation via sqrt SNS index and hunger was only significant for the MIST stress + uncertain safety condition but not the MIST stress + certain safety condition corroborates the notion that the results observed in Study One appear to be due to participants' concerns that they may encounter future stressors after the initial laboratory stressor. However, as shown in the analyses of the a priori hypotheses, it was not due to the impact of ongoing stress and low HRV on individuals' attentional bias towards or away from food. Rather, prolonged SNS activation appears to elicit a reduction in hunger that thereby attenuates consumption.

The link between SNS activation and reduced hunger is reasonable based on the physiological effects of an acute stressor. Upon the onset of a stressor, corticotropin-releasing hormone is released from the paraventricular nucleus of the hypothalamus to initiate the rest of the hypothalamic-pituitary-adrenal axis cascade and ultimately evokes secretion of cortisol approximately 15 min later (Appelhans et al., 2010). Corticotropin-releasing hormone is a powerful anorexigenic (i.e., appetite-suppressing) peptide (Mastorakos & Zapanti, 2004) that leads to a reduction in appetite (Sominsky & Spencer, 2014). In part, this appears to be due to corticotropin-releasing hormone's acute downstream reduction of ghrelin, an orexigenic (i.e., appetite-stimulating) hormone (Saegusa et al., 2011). Glucocorticoids also acutely prompt secretion of insulin from the pancreas which elevates blood sugar and thereby suppresses appetite (Herman et al., 1987; Sominsky & Spencer, 2014). Given these physiological effects, stress should suppress hunger (Herman et al., 1987), at least acutely.

Upon examining the conditional indirect effects, it was evident that the serial mediation was only significant among those with low dietary restraint. The negative coefficient for the interaction between restraint and hunger (i.e., b_3) reflects the fact that as restraint increased, lower hunger was associated with greater participant consumption. However, it is important to note the indirect effect was not significant at higher levels of restraint. These results seem to substantiate earlier proposals put forth in the restraint theory literature that unrestrained eaters significantly reduce their intake after certain types of threats because of hunger-inhibiting effects via "physiological (peripheral/autonomic) channels" (pg. 141), which unrestrained eaters were presumed to be more responsive to than their restrained counterparts (Heatherton et al., 1991). To this author's knowledge, however, this proposition had not been empirically tested until now.

4.4.2.2 *Dissociation of Hunger and Intake Among Restrained Eaters*

Although the current results are congruent with the notion that less restrained eaters are more responsive to hunger-inhibiting physiological influences, Heatherton et al.'s (1991) proposal was predicated on the notion that restrained eaters suppress or lose their ability to perceive hunger accurately (Kauffman et al., 1995). By this account, however, more restrained eaters arguably should not have exhibited a systematic relationship between SNS activity and hunger to a similar degree as less restrained eaters, in contrast to the current study's findings. Weight-Focused Restraint and Preoccupation with Dieting significantly moderated the pathway between hunger (M_2) and consumption (Y), but not between sqrt SNS index (M_1) and hunger (M_2). Thus, regardless of one's level of restraint, heightened SNS activity elicited by the MIST stress + uncertain safety condition led to the same degree of hunger suppression.

It is also interesting to note that over the repeated measurements of hunger throughout the laboratory protocol, hunger tended to increase from baseline to the measurement prior to the taste test. This increase in hunger makes sense given that participants were instructed not to eat for at least 2 hr prior and, by the time they reached the taste test, they had been in the laboratory for approximately 1 hr 15 min. The difference was that this increase from baseline to pre-taste test was suppressed for the MIST stress + uncertain safety condition, who also demonstrated a decrease in hunger after the perceived safety manipulation. More highly restrained eaters did not differentially report their hunger over time, suggesting that they could perceive hunger enough to capture these changes. The difference thus lay in the fact that, despite the SNS-induced suppression in hunger relative to controls, stressed highly restrained individuals still ate more.

Rather than suggesting highly restrained eaters suppress or lose their ability to perceive hunger, the current results seem to implicate they are disconnected from the ability to *respond* to hunger cues accurately and consistently. It is argued that this latter conclusion better accords with the theoretical construct of dietary restraint and empirical research to date. It has long been acknowledged in the literature that restrained eaters rely less on physiological or bodily cues to dictate their consumption (Herman et al., 1987). As noted in Chapter 2, restraint involves a set of rules that may concern when, how much, and what food they are "allowed" to eat (Fairburn, 2008). Eating is thus rule-driven instead of physiologically-driven. Indeed, previous research suggests a dissociation among restrained eaters between physiological cues indicative of hunger (e.g., ghrelin levels) and their corresponding intake (Myhre et al., 2014). Emotional or cognitive factors may thus be more predominant in dictating food consumption for these individuals.

If dietary restraint is intact and disinhibiting factors such as cognitive distraction or stress are not present, cognitively-mediated dietary rules might inhibit the expression of restrained eaters' physiological hunger (i.e., appropriate consumption of food) to discourage intake in the service of their dietary goals (Myhre et al., 2014). Under circumstances of stress or distraction, however, emotionally-driven or habit-driven food cravings or a general desire to eat may prevail regardless of their physiological hunger, returning to the notion of hedonic eating or "hedonic hunger" (Lowe & Butryn, 2007). Alternatively, changes in affect due to stress may activate restrained eaters' potential expectancies that eating can improve their mood (K. Smith et al., 2020) or prompt efforts to displace their distress onto something that may feel more controllable or less distressing than a threat to their broader sense of well-being (Polivy et al., 1994). Despite such conjectures, the current study is not capable of identifying the specific reason for the observed disconnection between hunger and intake for highly restrained eaters in this sample.

Though no studies have explored the relationship between SNS activity and hunger as it relates to dietary restraint, it might be relevant to consider studies that have examined the impact of stress or a "threat" on hunger among restrained and unrestrained eaters. Similar to the findings from the current study, a study by Loxton et al. (2011) found that a negative mood induction significantly decreased self-reported urge to eat irrespective of one's level of dietary restraint. These findings mirror the significant decrease in hunger that occurred due to SNS activation regardless of dietary restraint in the current study. However, as Loxton et al. (2011) did not examine food intake thereafter, it is unclear whether dietary restraint may have moderated a relationship between urge to eat and consumption. Further, as the negative mood induction involved watching an emotional scene from a movie, the experimental manipulation may have differed with regards to SNS activation. As noted earlier, stress and sadness both reduce HRV, however, stress is more likely to elicit parallel SNS activation (Thayer & Brosschot, 2005).

Contrary to the decrease in hunger observed in the current study, Wallis and Hetherington (2009) found a significant increase in hunger for restrained eaters after an ego-threatening Stroop task, with a similar, though nonsignificant pattern for unrestrained eaters. While the ego-threat condition was associated with significantly greater hunger in restrained eaters, they consumed significantly less than unrestrained eaters (Wallis & Hetherington, 2009). The lack of attenuation in hunger may be attributable to the fact that both the ego threat and control conditions elicited a significant increase in anxiety post-task and, though both conditions showed an increase in stress, the increase was not significant. As such, the experimental manipulation was not effective in creating a differentiated state of stress or threat. Wallis and Hetherington's (2009) findings may have also been impacted by the foods presented after the ego-threat task. Only one high-fat, highly palatable food (i.e., chocolate) was presented alongside a low fat alternative (i.e., dried fruit mix). Presentation of a low fat alternative may have served as an inhibiting cue for restrained eaters by enhancing the salience of dieting goals (Wallis & Hetherington, 2009). Consequently, Wallis and Hetherington's (2009) findings are not fully comparable to the current study, which elicited significant subjective and physiological stress via the MIST and presented multiple highly palatable foods in the taste test. Nonetheless, their results offer further evidence of a dissociation between hunger and food intake among highly restrained eaters, corroborating the conclusion that restrained eaters demonstrate difficulty in responding to their hunger appropriately. The evident dissociation between hunger and consumption for restrained eaters might reflect previous findings that restrained eating is associated with significantly lower interoceptive awareness, referring to metacognitive awareness and confidence in one's ability to accurately perceive and interpret bodily cues (Young, Williams, et al., 2017). Clinical implications and further reasons for the dissociation between hunger and consumption in restrained eaters will be discussed in Chapter 5.

4.4.3 Limitations and Future Directions

Although this study appears to be the first to examine the impact of HRV on attentional bias to food in restrained eaters, several limitations must be acknowledged. Despite null findings with respect to the serial mediation of the relationship between stress and consumption via HRV and attentional bias to food, additional studies are needed before definitive conclusions can be drawn given the visual-probe task's low reliability. As noted above, low reliability limits the capacity to observe a link between variables and reduces statistical power (Hardman et al., 2021). Efforts should be made to enhance the reliability of attentional bias to food scores in future studies. In the attentional bias to threat (MacLeod et al., 2019) and alcohol (Christiansen et al., 2015) literatures, it has been found that ensuring the personal relevance of stimuli enhances reliability in the visual-probe task. In the attentional bias to food literature, some authors (e.g., Ahern et al., 2010) have likewise opted to enhance personal relevance by individualizing food stimuli. However, as this would have required participants to rate food prior to their laboratory session, doing so would have drawn undue attention to the relevance of food and jeopardized the current study's validity. Arguably the best way to enhance measurement of attentional bias to food would be to use an attentional bias paradigm that exhibits more robust reliability. Eye tracking enables one to examine concurrent attentional focus during the presentation of the stimulus and can provide a more direct measure of the allocation of attention (van Ens et al., 2019). Eye tracking exhibits greater reliability than the visual-probe task, particularly when examining the relative proportion of time spent fixating on relevant stimuli relative to neutral stimuli (MacLeod et al., 2019), and would thus be a viable method to employ.

The current study was also limited by the relatively weak manipulation of perceived safety. Though there was some evidence that the MIST stress + uncertain safety condition exhibited higher ongoing stress than the MIST stress + certain safety condition via both subjective stress and SNS activity, the MIST stress + certain safety condition still exhibited substantial stress. The MIST stress + certain safety condition also self-reported significantly greater subjective stress than the control condition, despite the fact that it was lower than the MIST stress + uncertain safety condition. Furthermore, the two stress conditions did not significantly differ from one another on sqrt SNS index. Thus, the manipulation of perceived safety did not fully differentiate the two groups. Future studies could further examine whether perceptions of unsafety are a key determinant in whether stress-induced changes in eating behaviour occur using a stronger manipulation of perceived safety.

Despite the intriguing findings that emerged from the exploratory analyses herein, the serial moderated mediation effect via SNS activity and hunger should not be overstated. The Johnson-Neyman technique revealed that the effect was only significant for the lower 7.48% of the sample on Preoccupation with Dieting and the lower 8.84% on Weight-Focused Restraint.

With that said, Hayes (2018a) explains that the Johnson-Neyman technique is not a viable method for probing moderation of mediation as it assumes the distribution of the indirect effect is normal, which is untrue for all indirect effects. However, there is no appropriate analogue for probing moderation of an indirect effect (Hayes, 2018a). Given that the conditional indirect effects were not significant at the 16^{th}, 50^{th}, or 84^{th} percentiles, it is unclear for whom in the sample this effect is significant. Although these percentiles are taken to reflect "low," "moderate," and "high" levels of the moderator, the values are sample-specific. What is low in one sample could be moderate or high in another (Hayes, 2018a). As university-aged females exhibit high rates of dieting, body dissatisfaction, and disordered eating (Delinsky & Wilson, 2008), the range of dietary restraint values may have been constricted in this sample, thereby making differentiations between high and low restraint individuals more difficult. Future studies are needed to replicate these findings and determine for whom this moderated serial mediation effect via SNS activation and hunger may be evident. Including a broader sample of females across the lifespan and outside of a university context may be particularly beneficial.

Similar to Study One, the generalizability of these findings is also limited by features of the sample's demographics. Once again, only female participants were included for the reasons described in Chapter 2. The majority of the sample likewise reported Caucasian ethnicity. Though the current study expanded the sampling population beyond undergraduate students by recruiting graduate students, a small proportion of international exchange students, a few university staff members, and one college student, the sample remained highly White and educated (Henrich et al., 2010). Consequently, it is unknown whether these results will generalize to other populations.

4.4.3.1 ***Conclusion***

Altogether, in spite of the aforementioned limitations, the current study offers an interesting contribution to the literature. This study is the first to empirically demonstrate that unrestrained eaters demonstrate greater responsivity to the physiologically-based hunger-inhibiting effects of stressors with respect to subsequent ad libitum intake of food (Heatherton et al., 1991). Less restrained individuals significantly decrease their consumption of highly palatable food in accordance with SNS-induced decrements in hunger and, while individuals with higher dietary restraint exhibit comparable SNS-induced reductions in hunger, they tend to eat more food in a manner that is not systematically associated with their level of hunger. The current study may help advance the literature on dietary restraint through generating novel questions to explore. For example, is the dissociation between hunger and consumption in highly restrained eaters during stress a conscious process driven by eating expectancies (e.g., K. Smith et al., 2020), a product of low confidence in their ability to perceive bodily cues (e.g., Young, Williams, et al., 2017), or an unconscious tendency to eat during stress? Do restrained eaters experience an increased urge to eat or hedonic hunger, regardless of the source of the urge, despite a decrease in their physiologically-driven homeostatic hunger? Exploring these questions may enhance understanding of disinhibited eating in restrained individuals and assist in identifying ways to minimize episodes of disinhibition.

Chapter 5. General Discussion

The overarching objectives of the current program of research were to (a) clarify *how* dietary restraint may lead to stress-induced disinhibited eating by exploring the causal role of self-regulation using heart rate variability (HRV) as a physiological proxy; (b) explore the contextual circumstances under which more highly restrained eaters consume more than their less restrained counterparts; and (c) determine the role of attentional bias to food in evoking stress-induced changes in eating. Overall, this research suggests that individuals who exhibit higher dietary restraint show a relative disconnection from internal physiological cues shown to affect individuals' food intake when faced with stress. While other researchers have previously conjectured unrestrained eaters are more sensitive to autonomic effects on their eating behaviour (e.g., Heatherton et al., 1991), this study is the first to objectively substantiate this notion.

The general discussion herein serves to summarize and integrate the findings of Study One and Study Two, each of which were discussed comprehensively in Chapters 2 and 4, respectively. Consideration is also given to the broader implications of this research with regards to dietary restraint, disinhibited eating, and the role of self-regulation. Finally, this chapter will explore the plausible clinical implications, limitations of the overall program of research, and directions for future research.

5.1 Integrating Study One and Study Two

Both Study One and Study Two tested distinct causal pathways through which stress might lead to disinhibited eating among individuals with high dietary restraint. Although both studies were able to delineate a mechanism through which stress reduced eating in less restrained eaters, neither study was able to elucidate a significant causal pathway through which stress impacted eating for restrained eaters. Further, no evidence of significant disinhibited eating was found in highly restrained individuals and, in both studies, HRV and sympathetic nervous system (SNS) activity were unable to account for more highly restrained individuals' consumption. As articulated in Chapter 4, these results corroborate the notion that restrained eaters' consumption is not dictated by physiological cues of hunger or satiety (Herman & Polivy, 1983). While these findings might suggest two different ways through which unrestrained eaters' intake is influenced (i.e., via HRV and SNS activity), further examination of the findings could implicate a more parsimonious conclusion.

When comparing the timeline of both studies, it is critical to note that the taste test in Study One would have approximately aligned with the period during which the visual-probe task occurred in Study Two. It was revealed in Study Two that the differences in HRV elicited by the stress task across conditions had already attenuated during the visual-probe task. On this basis, it seems reasonable to speculate that, in the taste test in Study One, participants' HRV had likely already recovered to baseline or higher (Laborde et al., 2018). This arguably calls into question whether HRV was responsible for the reduction in consumption observed in Study One among the full sample and less restrained eaters. Additional analyses of the data from Study One revealed there was also a significant simple mediation, moderated mediation, and dual moderated mediation via the SNS index. Given the high correlation between PNS and SNS activity, it is possible that SNS activity might hold greater responsibility for the observed indirect effects via HRV in Study One. In essence, the mediation via HRV might have been spurious.

Alternatively, both PNS and SNS activity may reduce intake via similar means. Indeed, Mastorakos and Zapanti (2004) note short-term hunger and satiety signals provided by gut hormones are transmitted through both the vagus nerve and sympathetic fibres to the nucleus of the solitary tract in the brainstem, which assist in regulating eating behaviour. There could thus be a shared mechanism through which the PNS and SNS jointly impact eating. Conversely, divergent but parallel mechanisms in the PNS and SNS might reduce intake. Polyvagal theory notes that throughout evolution, the brainstem nuclei responsible for regulating the nucleus ambiguus, which is key in adjusting HRV, became integrated with the nuclei that control the striated muscles of the face and head (Porges, 2009). These somatic muscles, which govern facial expression, mastication, vocalization, swallowing, and sucking, are paired with general visceral efferents that project from the ventral nucleus ambiguus to exert potent effects on the heart and bronchi (Porges, 1995). Coupling of the nucleus ambiguus with facial and trigeminal nuclei creates the potential for coordination and bidirectional influences across the vagus nerve and muscles controlling eye gaze, facial expression, listening, and prosody (Porges, 2009). This has been primarily posited to create an integrated social engagement system in mammals, whereby low HRV attenuates one's propensity for social engagement (Porges, 1995). It seems reasonable to extrapolate from this proposition to suggest that, because of this physiological coupling, low HRV might reduce mastication and swallowing. It is thus possible low HRV might reduce consumption due to the vagus nerve's integration with facial muscles involved in eating.

The SNS's capacity to reduce consumption may be more linked to its associations with the hypothalamic-pituitary-adrenal axis. When a certain threshold is exceeded during a stressor, a systemic stress response occurs that involves both the hypothalamic-pituitary-adrenal axis and the SNS (Mastorakos & Zapanti, 2004). As articulated in Chapter 4, corticotropin-releasing hormone is a powerful anorexigenic (i.e., appetite-suppressing) peptide (Mastorakos & Zapanti, 2004) and stress can evoke insulin secretion, which acutely suppresses appetite (Herman et al., 1987; Sominsky & Spencer, 2014). Tomiyama et al. (2012) additionally found that increased circulating leptin (i.e., an anorexigenic hormone) concentrations during the Trier Social Stress

Test predicted reduced consumption of high fat, high sugar foods. Although Tomiyama et al. (2012) did not measure SNS activity, it is noteworthy that SNS activity regulates leptin production, which could suggest a mechanism through which SNS activity may attenuate intake. Ultimately, however, the current program of research cannot delineate whether SNS activity, PNS activity, or both are involved in the stress-induced reductions in consumption observed.

5.1.1 *Lack of Disinhibition*

Both studies also failed to find evidence of significant disinhibition among those who endorsed higher dietary restraint. One conjecture to explain this lack of disinhibition is that the time in between the stressor and taste test may not have been long enough given the typical hypothalamic-pituitary-adrenal axis cascade. Evidence suggests that cortisol's suppression of corticotropin-releasing hormone begins to occur 5-15 min after cortisol levels have risen, or about 35-45 min after stressor onset (Appelhans et al., 2010). Stress-induced appetite stimulation appears to be due to the effect of cortisol (Appelhans et al., 2010; Epel et al., 2001; George et al., 2010). Indeed, upon the suppression of corticotropin-releasing hormone, there is a subsequent cortisol-mediated stimulation of hunger and eating behaviour (Sominsky & Spencer, 2014). It is thus possible that corticotropin-releasing hormone might not have been inhibited by the time that participants reached the taste test. With corticotropin-releasing hormone-mediated appetite suppression still in effect, disinhibition may have been obscured.

As an alternative speculation, perhaps a stressor may need to cause parasympathetic withdrawal without SNS activation to elicit disinhibited eating. This dovetails with previous assertions from Chapter 2 that restrained eaters' disinhibition may have been suppressed due to the intensity of the laboratory stressor in this study, though they still tended to eat more relative to less restrained eaters. As discussed in greater depth below, however, it is also possible that the lack of disinhibited eating may have been due to conceptual issues vis-à-vis defining and identifying disinhibition. Regardless, the results offer novel, concrete evidence supporting a dissociation between physiological state and consumption among highly restrained eaters. In comparing Study One and Study Two, it must also be acknowledged that the latent restraint factors and conventional scales for which the models were significant differed across studies.

5.1.2 ***Differences Across Measures of Restraint***

Of note, the moderated mediation in Study One reflecting the indirect effect of stress on consumption via HRV (i.e., hypothesis one) was only significant for Hagan et al.'s (2017) latent dietary restraint factors Weight-Focused Restraint and Calorie Counting. The dual moderated mediation including frontal asymmetry (i.e., hypothesis two) was only significant for Weight-Focused Restraint. In Study Two, the exploratory serial moderated mediation model was only significant when using Weight-Focused Restraint and Preoccupation with Dieting. The most consistent restraint factor implicated across both studies was Weight-Focused Restraint, which conceivably raises the question as to why it was consistently implicated across the models.

It is noteworthy that in Study Two, Weight-Focused Restraint exhibited the strongest association with dieting status (i.e., "Are you currently dieting to lose weight?") relative to Calorie Counting and Preoccupation with Dieting. Accordingly, Weight-Focused Restraint could better reflect those who feel that they are eating less than they would like, whether there is a true caloric deficit or not (Presnell et al., 2008). This perceived or actual deprivation relative to one's energy needs may make these individuals prone to eat more than less restrained counterparts. It is further worth highlighting that in Hagan et al.'s (2017) study, Weight-Focused Restraint was significantly associated with elevated BMI and binge eating, as well as the EDI-3 eating disorder risk composite score. These individuals may thus be prone to develop eating pathology. With that said, Hagan et al. (2017) found all of the latent restraint factors were significantly associated with eating disorder risk, and Preoccupation with Dieting showed the strongest association.

Given associations with higher BMI and binge eating (Hagan et al., 2017), it was predicted both Weight-Focused Restraint and Preoccupation with Dieting would be the most important restraint factors in predicting stress-induced disinhibition. Although Preoccupation with Dieting was a significant moderator in the exploratory moderated mediation model from Study Two, it is interesting that it was not significant in Study One. As noted in Chapter 2, this discrepancy could have been due to weight bias in the RS items (Forbush et al., 2020) given the wide range of participants' BMIs and the unexpected group difference in EDI-3-DT scores. It is also interesting that Calorie Counting was a significant moderator in the moderated mediation model in Study One, though it was not significant in Study Two. The lack of moderation by Calorie Counting in Study Two may have been due to the fact that mean Calorie Counting scores in this sample were significantly higher relative to Study One. As the models were only significant for those with lower restraint, it is possible that Calorie Counting scores were not low enough in Study Two to capture the effect. It remains unclear whether Preoccupation with Dieting and Calorie Counting would moderate all of the observed effects across both studies barring the above factors. Overall, the specific dietary restraint factors implicated in the current findings require replication to discern which factors are most important and, ideally, why.

5.2 Broader Implications for Theory and Research

5.2.1 *Restraint Theory and Dietary Restraint*

Similar to other studies in the literature (Dritschel et al., 1993; Lowe & Maycock, 1988; Oliver et al., 2000; Ouwens et al., 2003, 2007; Steere & Cooper, 1993; Wardle & Beales, 1987), the evidence presented herein does not support the tenets of restraint theory. It has been proposed that null effects within prior studies may have been due to the use of restraint scales other than the RS (Dritschel et al., 1993; Ouwens et al., 2007). As the RS assesses changes in body weight, it is argued that it is not a "pure" measure of restraint, but rather, it is conflated with a tendency to overeat (Yeomans & Coughlan, 2009). The TFEQ-R and DEBQ-R, by contrast, measure attempts to restrict eating without consideration of body weight. Yeomans and Coughlan (2009) thus propose that women who score high on the RS reflect unsuccessful restrained eaters (i.e., those prone to disinhibition), whereas those high on the TFEQ-R and DEBQ-R may reflect both successful restrained eaters (i.e., those who maintain restraint) and those liable to overeat.

In line with the assertion that conceptual differences in the various measures of restraint may be responsible for null effects, there is some evidence that individuals' tendency towards restraint and disinhibition ought to be considered in tandem to predict disinhibited eating. Accordingly, some studies have shown that when classifying individuals based on their scores for disinhibition and dietary restraint (i.e., low restraint-low disinhibition, low restraint-high disinhibition, high restraint-low disinhibition, high restraint-high disinhibition), high restraint-high disinhibition individuals engage in disinhibited eating in response to a negative mood induction, while high-restraint-low disinhibition individuals do not (e.g., Fay & Finlayson, 2011; Haynes et al., 2003; Yeomans & Coughlan, 2009). Similar findings have also emerged in the preload paradigm (e.g., Westenhoefer et al., 1994). Nonetheless, some studies that included the RS alongside the TFEQ-R and DEBQ-R found no disinhibition effect among restrained eaters classified by the RS, TFEQ-R, or DEBQ-R (Dritschel et al., 1993; Ouwens et al., 2003, 2007).

Indeed, in the current research, disinhibition was not found with any of the most common measures of dietary restraint, including the RS, TFEQ-R, DEBQ-R, EDI-3-DT, and EDE-Q-R. Further, though not reported, the current program of research included the Disinhibition scale of the TFEQ (TFEQ-D) in both studies to explore the potential role of individuals' tendency towards disinhibited eating. However, the TFEQ-D did not predict disinhibition nor did it play a moderating role either in place of or in conjunction with restraint in the models. As alluded to in Chapter 2, it is possible that the inability to significantly predict disinhibition via either restraint or disinhibition in either of the studies may have been partially due to the use of regression-based analyses and not dichotomizing either restraint or disinhibition to create categorical groups, as most previous studies have done. van Strien et al. (2000) similarly did not find disinhibition when treating both restraint and disinhibition as continuous variables and using a regression-based approach. Future studies should arguably cease dichotomizing restraint given known limitations of dichotomization and the likelihood of Type I errors (MacCallum et al., 2002). Results in the current program of research generally corroborate recent concerns about the utility and predictive power of dietary restraint in predicting disinhibition (e.g., Johnson et al., 2012; Schaumberg et al., 2016), at least as disinhibition is currently conceptualized, as noted later.

The fact that the models analyzed in the current program of research were not consistent across each latent dietary restraint factor is unsurprising given an extensive body of literature highlighting differences between the conventional restraint scales that constitute each factor (e.g., Adams et al., 2019; Heatherton et al., 1988; Laessle et al., 1989; Mills et al., 2018; Polivy et al., 2020). An overview of such differences is beyond the scope of this research. However, the current results reemphasize that although existent measures of restraint have often been used interchangeably, these measures appear to be associated with different behavioural outcomes (Adams et al., 2019) and capture different aspects of dieting (Hagan et al., 2017). Beyond the fact that Weight-Focused Restraint was the most consistent moderator across studies, the strength and significance of associations between latent restraint factors and variables such as

BMI, current dieting status, and depressive symptoms differed. Researchers must ensure that they select an appropriate measure of dietary restraint that is relevant to their study's aim. Alternatively, similar to the current program of research, including all of the most common restraint measures may enable further distinctions across restraint scales to delineate the type of restrained eater to which an effect pertains. It is notable that the latent restraint factors exhibited excellent internal consistency, often exceeding that of the conventional scales, suggesting that these factors show high reliability and may even exceed the psychometric performance of extant restraint scales. These latent restraint factors may thus be useful to employ in future research.

The results of Study Two suggest those who exhibit high Preoccupation with Dieting or high Weight-Focused Restraint are less attuned to physiological cues associated with hunger in dictating their eating behaviour. Both restraint factors represent an intention or desire to control food intake primarily based on a desire to influence weight and shape. As such, these restraint factors may promote a particularly potent dissociation from hunger and satiety cues. Indeed, there is evidence to suggest individuals motivated to diet due to appearance concerns tend to use more drastic methods to lose weight and are more likely to report disinhibited eating or lapses in restraint (Polivy et al., 2020). By contrast, Calorie Counting may not necessarily promote such a dissociation. While Calorie Counting entails monitoring one's caloric intake, adhering to calorie limits, opting for lower calorie foods, and taking small portions of food (Hagan et al., 2017), it does not necessarily imply individuals are engaging in such behaviours for aesthetic reasons. These individuals may be motivated by health, a motive that is less prone to elicit disordered eating (Polivy et al., 2020). As such, distinguishing the motive behind Calorie Counting may be necessary to determine whether it will create a vulnerability towards eating pathology. More research is also warranted to further characterize each of the latent factors.

5.2.2 *Disinhibited Eating*

The current program of research did not find evidence of significant disinhibition as it has traditionally been operationalized in the literature to date. That is, more highly restrained eaters did not eat significantly more than their less restrained counterparts who were likewise physiologically stressed, nor did they eat significantly more than highly restrained individuals who were not stressed. However, a recent commentary from Polivy and Herman (2020) has called into question the meaning and conceptualization of “overeating,” casting doubt upon what is truly known about overeating and disinhibited eating among restrained eaters. As alluded to above, in this paradigm, overeating or disinhibition is often presumed to reflect an instance in which restrained individuals eat more after some aspect of the eating situation is manipulated than in the absence of that manipulation or in which restrained eaters eat more than unrestrained individuals exposed to the same manipulation (Polivy & Herman, 2020). This way of defining overeating might be problematic, as whether an eating episode constitutes overeating can vary situationally, and “overeating” is a relative term (Polivy & Herman, 2020). For example, a given amount of food may be identified as overeating if it is deemed a “snack” but not a “meal.” The extent to which an eating episode qualifies as overeating might also depend on an individual’s daily energy requirements and the amount of food they have already eaten that day. Individuals can also perceive the same amount of food differently (i.e., overeating vs. a normal eating episode) depending on their mood (Telch & Agras, 1996). Polivy and Herman (2020) admit their use of the term overeating may have been “somewhat cavalier” (p. 2). Objectively eating an excessive amount (i.e., exceeding daily energy requirements), subjectively-perceived overeating (i.e., feeling one has eaten more than they feel is appropriate or violating a personal norm/diet), and eating more than others (i.e., violating a situational social or societal norm) are different phenomena that have often been conflated when discussing overeating (Polivy & Herman, 2020).

It is especially vital to clarify that "disinhibited eating" is not fully synonymous with overeating (Polivy & Herman, 2020). Disinhibition inherently necessitates that an individual's eating is inhibited in some regard in order for it to become disinhibited. While in some instances an episode of disinhibition may lead to the consumption of an objectively excessive amount, it can be argued that the crux of disinhibition is that a restrained eater has violated their dietary rules and perceives that they have broken their diet. Thus, there is only overlap between disinhibition and overeating insofar as overeating can be defined based on an individual's own personal standards or intentions for consumption (Polivy & Herman, 2020). That is, when a restrained eater transgresses their dietary goals or rules, they may classify their eating as "overeating," even if the actual quantity consumed was less than an unrestrained eater might eat (Polivy & Herman, 2020). Furthermore, while there may be commonalities in the types of foods deemed "forbidden" or off-limits (Guertin & Conger, 1999; Knight & Boland, 1989) that would violate one's diet, the specific dietary rules restrained eaters possess can differ from person to person. For instance, one individual may perceive having more than one cookie as violating their diet, whereas another may view eating any cookies as a lapse in restraint. Polivy and Herman (2020) highlight that the types of foods utilized in this paradigm (i.e., high calorie, high fat snack foods) may inherently be perceived as diet-breaking, regardless of the amount consumed.

When conceptualized in this manner, failing to find a significant difference in the quantity of food consumed between restrained and unrestrained eaters does not necessarily enable the conclusion that restrained eaters did not become disinhibited. All that can be concluded is that restrained eaters did not consume more than unrestrained eaters, reflecting the fact that they did not overeat from a social norm perspective. In a related vein, studies of restraint theory to date only speak to the fact that, under certain conditions, restrained eaters eat more than their less restrained counterparts. Undeniably, this does not detract from the importance of previous findings in the restraint theory literature. It does, however, call for reconsideration with regards to how future studies conceptualize and study disinhibition. In the absence of a concrete operational definition, it could arguably be asserted that eating despite a reduction in one's hunger reflects disinhibition. For restrained eaters in Study Two, their eating was not inhibited by low sensations of hunger that would normally suppress their consumption. This reemphasizes the importance of establishing a clear definition to isolate the phenomenon of interest.

There may be utility in distinguishing between objective and subjective disinhibition, effectively mirroring the distinction between objective and subjective binge episodes in clinical eating disorders and subclinical eating pathology (Jenkins et al., 2012). This distinction may be particularly relevant given that disinhibition is deemed "the theorized analogue of bingeing" (Guertin & Conger, 1999; p. 176). Whereas an objective binge episode encompasses perceived loss of control over eating in conjunction with the consumption with a large amount of food, subjective binge episodes involve loss of control during an eating episode without consuming an objectively large amount of food (Jenkins et al., 2012). It is conceivable that restrained eaters may perceive that they have broken their diet or overeaten (i.e., lost control) without necessarily eating significantly more food than less restrained individuals when faced with a disinhibitor such as stress or negative affect. As discussed earlier, some studies in the literature have found comparable results to those in the current research wherein restrained eaters ate nonsignificantly more than their less restrained peers while unrestrained ate significantly less (e.g., Heatherton et al., 1991; Herman & Polivy, 1975). Though some researchers might assert disinhibition is only meaningful if it leads to objective overeating or eating more than less restrained peers due to weight gain risks, it is argued that even subjective disinhibition could be consequential.

Studies of objective and subjective binge eating have shown that the perception of loss of control is more clinically relevant than the quantity of food consumed during an eating episode (e.g., Jenkins et al., 2012; Li et al., 2019; Mond et al., 2010). In a nonclinical sample, Jenkins et al. (2012) found those who exhibited subjective or objective binge eating episodes reported significantly higher eating disorder psychopathology, general psychopathology, and impairment in quality of life relative to those who did not experience loss of control while eating. Most notably, those who engaged in either subjective or objective binges did not significantly differ (Jenkins et al., 2012). Mond et al. (2010) likewise found no significant differences across individuals with objective and subjective binge episodes on a number of pertinent variables including eating disorder psychopathology, general psychological distress, impairment in role functioning, and impairment in quality of life. Furthermore, the findings of Telch and Agras (1996) emphasize the importance of subjective experiences in defining binge eating. Among women with binge eating disorder, affective state differentiated whether they labelled an eating episode as overeating or a binge. Though caloric intake did not significantly differ across episodes labelled as overeating or binge eating, women with binge eating disorder who labelled their eating as a binge reported significantly greater negative affect afterwards than those who categorized it as overeating (Telch & Agras, 1996).

One can surmise that a similar distinction between subjective and objective disinhibition may be relevant for restrained eaters' disinhibited eating. Whether eating more than a social norm or engaging in eating that breaks one's dietary rules, the outcome may be feelings of guilt and self-disappointment (Polivy et al., 2020). The guilt caused by the initial transgression of one's diet can then promote continued eating (Polivy et al., 2020). In essence, restrained eaters may think that if they have already broken their diet, they may as well enjoy themselves in the short-term before they resume their efforts to diet (Polivy & Herman, 2020). Even though this might not necessarily lead to objective overeating, this could reasonably lead to patterns of disordered eating or less healthful nutritional intake. Thus, theoretically, both subjective and objective disinhibition could be meaningful to distinguish. Exploring both subjective and objective disinhibition might also reframe questions about the heterogeneity of restrained eaters' vulnerability to disinhibition (Schaumberg et al., 2016). Do restrained eaters vary in their vulnerability to become disinhibited or in their proclivity to objectively overeat when disinhibited? Researchers should begin to consider this nuance in their continued attempts to better understand restrained eaters. Greater nuance appears to be additionally warranted in conceptualizing the role of self-regulatory capacity in predicting restrained eaters' consumption.

5.2.3 *The Role of Self-Regulation*

The current program of research sought to establish whether self-regulation explains stress-induced disinhibition by using HRV as a psychophysiological proxy for self-regulatory capacity. Though HRV did not elicit disinhibition, the current results do not nullify the plausible importance of self-regulation. The findings from Study Two could arguably suggest a role for self-regulation, though it may not operate via an automatic psychophysiological mechanism such as HRV. Rather, there may be a more complex association between autonomic activation and variables that determine individuals' ability to effectively self-regulate their food intake.

Referring back to Chapter 1, Schaumberg et al. (2016) articulate self-regulation consists of self-monitoring, self-evaluation, and self-reinforcement. While Schaumberg et al. (2016) suggest self-monitoring reflects being aware of and tracking one's intake, self-monitoring could also conceivably refer to one's ability to monitor physiological cues of hunger. As Young, Williams, et al. (2017) articulate, self-regulation necessitates that one is first able to actively monitor and be aware of ongoing internal processes. The exploratory model in Study Two indicated restrained eaters did not appropriately modify their food consumption in accordance with their reduction in hunger when experiencing high SNS activity. As noted in Chapter 4, restrained eaters appear to exhibit lower interoceptive awareness, reflecting lower metacognitive awareness and confidence in their ability to accurately perceive and interpret bodily cues (Young, Williams, et al., 2017). Low interoceptive awareness might make it more difficult for restrained eaters to actively monitor their bodily signals in a way that enables them to take appropriate action (Young, Williams, et al., 2017), reflecting worse self-regulatory capacity in this regard. It is unclear from the current program of research whether this failure to self-regulate consumption based on hunger occurs through conscious or unconscious processes.

It remains possible that restrained eaters may eat in the absence of hunger following a disinhibitor (e.g., stress) due to a consequent reduction in the capacity for self-regulatory control. This alludes back to the notion of ego depletion whereby prior exertion of self-control diminishes an individual's resources for further self-control (Baumeister et al., 2007). It is theorized that ego depletion can undermine conscious inhibition of desires (Baumeister, 2014). When stressed, restrained eaters may not be able to inhibit or regulate hedonic desires to eat highly palatable foods that are typically avoided. From the perspective of Stroebe et al. (2008), restrained eaters may anticipate the pleasure of eating, which may lead to the abandonment of the more effortful goal of controlling their eating to pursue the goal of eating enjoyment. Either this process simply may not be mediated by HRV or, alternatively, key variables may have been left out of the model, such as individuals' level of hedonic hunger. There is some evidence to suggest a link between higher resting HRV and a greater ability to exert control over one's food cravings, at least within the context of a hypothetical dietary choice task (Maier & Hare, 2017). Further, stress enhances cravings and motivational incentive to obtain desired foods in the absence of hunger among individuals vulnerable to weight gain (Lemmens et al., 2011). Perhaps low HRV during stress may thus make restrained eaters less able to downregulate their food cravings and thereby increase hedonic hunger and desire for food. However, this remains to be empirically investigated. Returning to the process model of ego depletion, the shift in motivation and attentional focus towards gratifying desires said to occur during a state of ego depletion (Inzlicht & Schmeichel, 2012) may be better accounted for by examining alterations in hedonic hunger. As theorized in Chapter 4, when stressed, distracted, or experiencing negative affect, restrained eaters' food cravings or desire to eat may prevail regardless of physiological hunger, reflecting hedonic hunger (Lowe & Butryn, 2007). Researchers should distinguish between restrained eaters' physiological hunger and hedonic hunger, desire to eat, or food cravings when trying to understand the underlying mechanisms of disinhibition and the role of self-regulation therein.

It is additionally notable that only restrained eaters who remained uncertain about their ongoing safety in the laboratory and who exhibited greater ongoing SNS activation showed a dissociation between their hunger and eating behaviour. This could likewise point towards a role for self-regulatory processes in stress-induced eating patterns. As distress dampens the prefrontal cortex's control over behavior (Thayer et al., 2012; Wagner et al., 2012) and the prefrontal cortex is significantly implicated in self-regulatory behaviour and executive functioning (Suchy, 2009), additional consideration of the role of self-regulation appears to be warranted.

5.3 Plausible Clinical Implications

Before considering potential clinical implications of the findings herein, it is emphasized that the proceeding musings remain highly speculative. Additional research is needed to substantiate these extrapolations. Nevertheless, the findings have plausible clinical implications insofar as they contribute to novel perspectives on disinhibition as a laboratory analogue for binge eating. Conceptualizations of eating disorders have notably shifted towards a transdiagnostic approach reflecting the commonalities across diagnoses in development and maintenance that implicates dietary restraint as a central factor in precipitating and perpetuating eating disorders (Fairburn, 2008; Hagan et al., 2017). Indeed, a large, three-year prospective cohort study of 14- and 15-year olds showed dieting was the most important predictor of eating disorder development (Golden et al., 2016). Further, relevant to concerns about rising obesity rates, restraint predicts weight gain over time (Dong et al., 2015; van Strien et al., 2014). Longitudinal studies with youth likewise show dieting predicts future weight gain, with evidence to suggest an increase in binge eating mediates this link (Field et al., 2003; Neumark-Sztainer et al., 2007). The current findings may thus generate ideas about how to attenuate the risk of persistent binge-restrict cycles, progression to an eating disorder, and the risk of obesity.

The central notion behind restraint theory is that it is the overreliance on cognitive control instead of physiological cues to dictate eating that makes restrained eaters vulnerable to overeat or engage in disinhibited eating (Herman & Polivy, 1980). While most literature centres around identifying factors that make individuals vulnerable to disinhibition in an attempt to enhance their ability to maintain restraint, findings from the current program of research in conjunction with prior research suggest a paradigm shift might be warranted (Bacon & Aphramor, 2011). Rather than trying to improve maintenance of restraint, there would arguably be benefit in enhancing restrained eaters' ability to be attuned to their hunger and satiety cues and to use these cues to guide their eating. Facilitating responsiveness to interoceptive signals could feasibly reduce their proclivity towards disinhibition. It is also relevant to highlight that there are parallels between the current research and previous findings in those with an eating disorder. In a clinical sample of 15 women with bulimia nervosa, subjective binge episodes were more likely to occur in response to a food craving when they reported higher tension and lower hunger (Waters et al., 2001), mirroring the finding that restrained eaters ate more when they were more stressed and less hungry. As those with bulimia nervosa exhibit high dietary restraint (Fairburn, 2008), this further calls into question whether enhancing success in maintaining restraint is a prudent goal.

Interventions aimed to encourage intuitive eating may be an ideal alternative to promote healthy eating behaviour. Intuitive eating is a weight-neutral alternative to weight-loss focused treatments that aims to improve health across the weight spectrum from a non-dieting stance (Romano et al., 2018). Intuitive eating promotes attending to one's hunger and satiety signals and trusting those signals to guide eating rather than relying on external signals, rules, or negative emotions (J. Smith et al., 2020). Intuitive eating also involves heeding the needs of one's body in making food choices while giving oneself unrestricted permission to eat the foods one desires when hungry (Romano et al., 2018; J. Smith et al., 2020). Intuitive eating is associated with a lower BMI on average, and it has positive effects on cholesterol and triglyceride levels, systolic blood pressure, eating disorder and depressive symptoms, body dissatisfaction, and self-esteem (Romano et al., 2018). In essence, intuitive eating appears to pose benefits for attenuating the likelihood of obesity and related health concerns while also protecting against disordered eating. As might reasonably be expected from a conceptual standpoint, there is a significant negative link between restraint and intuitive eating, especially among women (J. Smith et al., 2020).

Targeting individuals who endorse high dietary restraint via intervention and prevention efforts aimed to increase intuitive eating (e.g., Burnette & Mazzeo, 2020) may thus be beneficial. Doing so could help restrained eaters examine and modify the reasons underlying their episodes of eating beyond satiety and promote an understanding of how a lack of unconditional permission to eat what they desire when hungry may actually be counterproductive to their health goals. Interventions aimed to enhance individuals' interoceptive sensitivity could also be of utility, as evidence suggests a positive relationship between intuitive eating and interoceptive sensitivity (Herbert et al., 2013; Richard et al., 2019). Interoceptive sensitivity also mediates the relationship between intuitive eating and BMI (Herbert et al., 2013). It is thus reasonable to suggest that a greater ability to perceive one's internal cues can enhance the ability to use those cues to guide eating. As interoceptive sensitivity facilitates effective emotion regulation (Füstös et al., 2013), interventions that more broadly aim to enhance interoceptive sensitivity may also attenuate the likelihood of stress-induced changes in eating by enabling alternative coping.

Novel intervention approaches facilitated by advances in mobile technology could be of utility to enhance intuitive eating practices and interoceptive sensitivity. Just-in-time adaptive interventions (JITAIs) can deliver an intervention via a smartphone when individuals need support the most (Godfrey et al., 2019). Though JITAIs often rely upon self-report, this may create burden on individuals through repetitive daily prompts (Godfrey et al., 2019). Godfrey et al. (2019) propose that incorporating psychophysiological measures into such technology could enable passive data collection while also identifying high-risk moments when individuals would benefit from an intervention. Perhaps prompting highly restrained individuals to mindfully reflect on their hunger sensations or providing coaching in relevant emotion regulation strategies when exhibiting low HRV and/or high SNS activity could attenuate stress-induced eating.

5.4 Limitations and Future Directions

Limitations and future directions pertinent to each study are discussed in Chapters 2 and 4, respectively. Broader limitations and future directions applicable to the program of research in its entirety are considered here. Of primary concern, it must be acknowledged that the construct validity of HRV as a proxy for self-regulation is weak. Numerous psychophysiological factors can impact HRV, such as stress, age, physical conditioning, and compassion, among many other situational and individual variables (Laborde et al., 2017; T. Smith et al., 2020). Furthermore, it has recently been emphasized that since HRV is associated with a variety of psychosocial constructs, it is difficult to equate HRV to a specific aspect of emotional, interpersonal, or self-regulatory functioning (T. Smith et al., 2020). As such, HRV is not an ideal candidate for future studies attempting to establish the role of self-regulatory capacity in prompting disinhibited eating. Nevertheless, research investigating the role of HRV in eating behaviour is arguably still worthwhile and could offer novel avenues for intervention within disordered eating.

Another central limitation is that a laboratory-induced stressor may differ relative to stress in real life and, as a result, the observed effect on intake may not generalize to naturalistic stressors outside of this setting. Studies that employ ecological momentary analysis and ambulatory Holter monitoring of HRV akin to Ranzenhofer et al. (2016) could be useful to discern whether HRV or SNS activity predict stress-induced eating in individuals' daily lives. It would also be fruitful to append an ecological momentary analysis component to experimental studies to assess eating after the laboratory session. As Evers et al. (2018) aptly note, laboratory studies that examine the interaction between eating and emotions only assess a fixed point in time and cannot capture how eating unfolds over time. Theoretically, if restrained eaters' diets are violated by the foods they consume in the laboratory, this may lead to more eating later that day. Though Wardle and Beales (1987) did not find any difference in consumption throughout the remainder of the day after a laboratory preload, it is unknown whether stress may lead to an increase in caloric consumption or in the proportion of calories consumed from highly palatable foods after the laboratory session.

In addition to the use of a laboratory stressor, the type of food presented in the taste test might also limit the ecological validity of the current research. Pool et al. (2015) contend that the specific foods one habitually eats under stress impact the food that is sought for consumption when stressed. The foods that were offered in the taste test might have differed from the typical food choices of the participants studied, which could have affected the extent of their intake. However, given the design of the current research, asking participants about their favourite foods to eat under stress prior to the study would have made the research objective unduly transparent, thereby interfering with the strategic deception used to obscure the stress task and the focus on eating. It is also possible that providing both sweet and savoury foods could have better reflected the array of food types available after a stressor. Future studies could examine whether access to preferred foods or a wider variety of foods impact these results. A further limitation concerns the integrity of the deception. In hindsight, it would have been beneficial to include a structured debriefing to ascertain whether participants believed the cover story and to assess what each participant thought the studies were examining. Some participants may have deduced that their intake was under scrutiny in the context of this research, which might have affected their consumption (Robinson et al., 2015). It is unknown to what extent this could have affected the conclusions derived herein. Future studies should ensure the deception is robust and believed.

As mentioned earlier, the current results cannot conclusively determine whether the temporary reduction in intake observed in individuals with low dietary restraint was attributable to the causal effect of stress on HRV, SNS activity, or a combination of the two. It is additionally unknown whether the intensity of the chosen laboratory stressor was responsible for the lack of traditionally-defined disinhibition. Future research could strive to tease apart the contributions of the PNS and SNS in eliciting stress-induced alterations in eating by testing various experimental manipulations that differentially alter the degree of PNS and SNS activity. Limitations in the PNS and SNS indices utilized must also be acknowledged. While the PNS index is computed via evidence-based parameters reflecting cardiac vagal tone (Brennan et al., 2001; Kubios Oy, 2019; Shaffer & Ginsberg, 2017) and the SNS index is calculated from metrics that index sympathetic tone (Baevsky & Chernikova, 2017; Kubios Oy, 2019), neither index has been formally validated. Nevertheless, recent peer-reviewed studies have used these indices (e.g., Combertaldi & Rasch, 2020; Flasbeck et al., 2020; Melo et al., 2019). In future studies, including additional psychophysiological metrics that reflect sympathetic tone such as skin conductance (Critchley et al., 2000) or salivary alpha-amylase (Rohleder et al., 2004) could corroborate the degree of SNS activity. HRV analyses may also be limited by the lack of consideration for individuals' typical alcohol consumption, habitual physical activity level, and sleep quality, all of which can affect HRV (Laborde et al., 2017; T. Smith et al., 2020). However, reported fatigue was not associated with HRV and it is likely that differences in habitual alcohol intake and physical activity were balanced across the groups through randomization. Future studies that assess HRV in this context should assess such factors to statistically control for their potential impact on HRV nonetheless.

Some concern could also be warranted about measuring restraint after the taste test. Individuals might respond differently if they feel guilty about eating "forbidden" foods and breaking dietary rules or if they feel virtuous for resisting temptation (Polivy et al., 2020). However, it was not deemed prudent to provide the restraint questionnaires for completion prior to the laboratory session as doing so might have revealed the studies' focus on eating. Including an assessment of how participants' felt about their consumption (e.g., good vs. bad, guilty vs. virtuous) could enable the possible impact of this factor to be statistically controlled in future studies. It is also worth noting that the restraint measures were administered close to the end of the laboratory sessions in both studies, which may have been quite long for participants. Some participants might have tried to complete these questionnaires quickly due to response fatigue, and as such, their responses may not have been as accurate or thoughtful as possible (Egleston et al., 2011). Future studies ought to assess the possible impact of response fatigue on responding and shorten study protocols where possible. In addition, it was not assessed whether individuals had a current or past diagnosis of an eating disorder. In retrospect, this was an oversight. As those with an eating disorder may differ from nonclinical individuals with high restraint and there could be the possibility for psychological harm, future studies should exclude those with a current or past eating disorder.

Unfortunately, the current research cannot speak to the function that eating in the absence of hunger may serve for restrained eaters, if any. Nevertheless, multiple hypotheses have been put forth over the years regarding the function disinhibition may fulfill more generally (e.g., Heatherton & Baumeister, 1991; Polivy et al., 1994; K. Smith et al., 2020). Despite slight conceptual differences, all of these hypotheses centre around the notion that disinhibited eating may be an attempt to regulate distress, regardless of its actual effectiveness, suggestive of poor emotion regulation skills. Akin to the regulation of eating (Young, Williams, et al., 2017), effective emotion regulation also requires interoceptive awareness (Füstös et al., 2013). Future studies could benefit from examining whether interoceptive sensitivity and emotion regulation capacity moderate the likelihood of eating in the absence of hunger for restrained eaters. If further replicated, future research could also examine the origins of the dissociation between hunger and eating in restrained eaters. For example, does it arise due to prolonged disregard for physiological cues in guiding intake or do restrained eaters experience an opposing increase in hedonic hunger or food cravings under stress? These questions remain to be answered.

5.5 Concluding Remarks

The results from Study One and Study Two offer unique insight into previous findings on restrained eaters. The observed dissociation between physiological variables that can indirectly impact individuals' appetite (e.g., autonomic activity) as well as between self-reported hunger itself and eating among restrained eaters is an intriguing finding that prompts new research questions. In particular, it calls into question whether the uncoupling of hunger and consumption is conscious or unconscious, what function this eating behaviour may serve if it is consciously-driven, and how this dissociation might occur. Though preliminary and remaining to be replicated, these findings might progress the restraint literature forward through encouraging an integration of psychophysiological variables, emphasizing the role of interoceptive sensitivity, and questioning the impact of the way in which disinhibition is defined.

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Table 1

Dietary Restraint Items of the TFEQ, DEBQ, RS, EDEQ, and EDI Comprising Hagan et al.'s (2017) Latent Dietary Restraint Factors

Calorie Counting	Weight-Focused Restraint	Preoccupation with Dieting
TFEQ: 6	DEBQ: 1	RS: 1
TFEQ: 10	DEBQ: 2	RS: 8
TFEQ: 14	DEBQ: 3	RS: 9
TFEQ: 18	DEBQ: 4	RS: 10
TFEQ: 21	DEBQ: 5	EDI: 1R
TFEQ: 23	DEBQ: 6	EDI: 5R
TFEQ: 28	DEBQ: 7	EDI: 7R
TFEQ: 30	DEBQ: 8	EDI: 9R
TFEQ: 32	DEBQ: 9	EDI: 11R
TFEQ: 33	DEBQ: 10	EDI: 14R
TFEQ: 35	EDE-Q: 1	EDI: 19R
TFEQ: 40	EDE-Q: 2	
TFEQ: 42	EDE-Q: 3	
TFEQ: 43	EDE-Q: 4	
TFEQ: 44		
TFEQ: 46		
TFEQ: 48		
TFEQ: 50		

Note. TFEQ = Three-Factor Eating Questionnaire; DEBQ = Dutch Eating Behaviour Questionnaire; EDE-Q = Eating Disorder Examination-Questionnaire; RS = Restraint Scale; EDI = Eating Disorder Inventory.

Table 2

Descriptive Statistics of Continuous Dependent Variables and Sample Characteristics by MIST Condition in Study One

Variables	MIST control condition (n = 50)		MIST stress condition (n = 47)	
	M (*SD*)	$z_{skewness}$	*M* (*SD*)	$z_{skewness}$
Age (in years)	20.58 (4.72)	8.98	20.36 (5.17)	12.17
BMI	25.19 (4.59)	4.12	24.46 (5.12)	3.03
Calorie Counting	6.07 (4.24)	0.77	6.71 (3.30)	0.91
Preoccupation with Dieting (sqrt)	3.23 (1.37)	0.22	3.71 (1.30)	-1.01
Weight-Focused Restraint (sqrt)	5.27 (1.27)	0.60	5.23 (1.06)	-0.30
TFEQ-R	6.77 (4.65)	0.53	7.37 (3.63)	0.64
DEBQ-R	2.36 (0.83)	0.75	2.36 (0.77)	0.21
EDI-DT (sqrt)	2.14 (1.48)	0.51	2.74 (1.37)	-1.02
EDE-Q-R (sqrt)	0.92 (0.66)	0.47	0.96 (0.51)	-0.002
RS	13.16 (5.22)	0.76	13.61 (5.40)	0.77
Baseline ln RMSSD	3.52 (0.55)	0.10	3.68 (0.50)	0.19
Baseline ln PNS Index	1.44 (0.27)	0.46	1.47 (0.23)	-2.03
ln RMSSD during MIST	3.58 (0.56)	0.84	3.51 (0.52)	1.14
ln PNS Index during MIST	1.43 (0.29)	1.11	1.32 (0.27)	0.06
ln Frontal asymmetry during MIST	-0.01 (0.25)	-9.18	-0.03 (0.19)	-13.93
Food consumption in g (sqrt)	7.32 (2.20)	0.49	6.09 (2.06)	0.63

Note. *N* = 97. TFEQ-R = Three-Factor Eating Questionnaire – Restraint scale; DEBQ-R = Dutch Eating Behaviour Questionnaire – Restrained Eating scale; EDI-3-DT = Eating Disorder Inventory-3 – Drive for Thinness scale; EDE-Q-R = Eating Disorder Examination-Questionnaire Restraint scale; RS = Revised Restraint scale; BMI = Body mass index; sqrt = Square root transformed value of variable; ln RMSSD = Natural logarithm transformed root mean square of successive differences; ln PNS index = Natural logarithm transformed parasympathetic nervous system index; ln Frontal asymmetry = Natural logarithm transformed frontal asymmetry; MIST = Montreal Imaging Stress Task.

Table 3

Unstandardized Regression Coefficients, SEs, and 95% CIs of PROCESS Model 14 Estimating Participant Consumption (Y) from MIST Condition (X) through HRV indices (M) as Moderated by Hagan et al.'s (2017) Latent Calorie Counting Factor (W)

	Consequent			
	Model A: ln RMSSD (M_1)		Participant consumption (Y)	
Antecedent	Coeff. (*SE*)	95% CI	Coeff. (*SE*)	95% CI
MIST condition (X)	-0.208*** (0.058)	**-0.323, -0.094**	-0.574 (0.427)	-1.422, 0.273
ln RMSSD (M)	--	--	3.438*** (0.815)	**1.819, 5.058**
Calorie Counting (W)	--	--	0.996*** (0.281)	**0.438, 1.555**
$X \times W$	--	--	-0.275*** (0.080)	**-0.434, -0.115**
Constant	0.416 (0.382)	-0.343, 1.174	-3.941 (2.565)	-9.037, 1.156
	$R^2 = 0.755$ $F(3, 93) = 72.614$***		$R^2 = 0.379$ $F(6, 90) = 10.720$***	
	Consequent			
	Model B: ln PNS Index (M_1)		Participant consumption (Y)	
Antecedent	Coeff. (*SE*)	95% CI	Coeff. (*SE*)	95% CI
MIST condition (X)	-0.144*** (0.028)	**-0.200, -0.088**	-0.485 (0.462)	-1.403, 0.434
ln PNS Index (M)	--	--	7.054*** (1.743)	**3.590, 10.518**
Calorie Counting (W)	--	--	0.764* (0.291)	**0.186, 1.342**
$X \times W$	--	--	-0.529* (0.211)	**-0.948, -0.110**
Constant	0.107 (0.153)	-0.197, 0.410	-2.685 (2.350)	-7.354, 1.983
	$R^2 = 0.789$ $F(3, 93) = 151.861$***		$R^2 = 0.376$, $F(6, 90) = 9.983$***	

Note. $N = 97$. CI = Confidence interval; ln RMSSD = Natural logarithm transformed root mean square of successive differences; ln PNS index = Natural logarithm transformed parasympathetic nervous system index. All models control for baseline HRV measures and average liking of food items. Bolded 95% CIs do not straddle zero.

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 4

Unstandardized Regression Coefficients, SEs, and 95% CIs of PROCESS Model 14 Estimating Participant Consumption (Y) from MIST Condition (X) through HRV indices (M) as Moderated by Hagan et al.'s (2017) Latent Weight-Focused Restraint Factor (W)

	Consequent			
	Model A: ln RMSSD (M_1)		Participant consumption (Y)	
Antecedent	Coeff. (SE)	95% CI	Coeff. (SE)	95% CI
MIST condition (X)	-0.208*** (0.058)	**-0.323, -0.094**	-0.550 (0.428)	-1.399, 0.300
ln RMSSD (M)	--	--	6.061*** (1.515)	**3.051, 9.071**
Wt Foc Restraint (W)	--	--	2.828** (0.935)	**0.971, 4.685**
$X \times W$	--	--	-0.816** (0.262)	**-1.337, -0.295**
Constant	0.416 (0.382)	-0.343, 1.174	-12.442* (5.314)	**-22.999, -1.885**
	$R^2 = 0.755$ $F(3, 93) = 72.614$***		$R^2 = 0.360$ $F(6, 90) = 9.761$***	
	Consequent			
	Model B: ln PNS Index (M_1)		Participant consumption (Y)	
Antecedent	Coeff. (SE)	95% CI	Coeff. (SE)	95% CI
MIST condition (X)	-0.144*** (0.028)	**-0.200, -0.088**	-0.443 (0.461)	-1.360, 0.473
ln PNS Index (M)	--	--	12.670*** (3.666)	**5.387, 19.954**
Wt Foc Restraint (W)	--	--	2.333* (0.922)	**0.501, 4.165**
$X \times W$	--	--	-1.705 (0.661)	**-3.019, -0.391**
Constant	0.107 (0.153)	-0.197, 0.410	-10.139 (5.004)	**-20.079, -0.199**
	$R^2 = 0.789$, $F(3, 93) = 151.861$***		$R^2 = 0.358$, $F(6, 90) = 10.343$***	

Note. $N = 97$. CI = Confidence interval; Wt Foc Restraint = Weight-Focused Restraint square root transformed; ln RMSSD = Natural logarithm transformed root mean square of successive differences; ln PNS index = Natural logarithm transformed parasympathetic nervous system index. All models control for baseline HRV measures and average liking of food items. Bolded 95% CIs do not straddle zero.

*$p < .05$, **$p < .01$, ***$p < .001$

Table 5

Unstandardized Regression Coefficients, SEs, and 95% CIs Testing the Conditional Indirect Effect of MIST Condition (X) on Participant Consumption (Y) through Mediating HRV Indices at Moderating Levels of Hagan et al.'s (2017) Latent Restraint Factors (W)

	Model A: ln RMSSD MIST (M_1)		Model B: ln PNS Index MIST (M_1)	
Calorie Counting (*W*)	*b* (*SE*)	95% CI	*b (SE)*	95% CI
ab_3	0.057 (0.022)	**0.021, 0.107**	0.076 (0.031)	**0.030, 0.151**
16th = 2.000	-0.601 (0.239)	**-1.129, -0.202**	-0.863 (0.289)	**-1.486, -0.345**
50th = 6.320	-0.354 (0.191)	**-0.775, -0.033**	-0.534 (0.235)	**-1.013, -0.085**
84th = 10.000	-0.144 (0.181)	-0.541, 0.182	-0.254 (0.244)	-0.725, 0.246
	Model A: ln RMSSD MIST (M_1)		Model C: ln PNS Index MIST (M_1)	
Weight-Focused Restraint (*W*)	*b* (*SE*)	95% CI	*b (SE)*	95% CI
ab_3	0.170 (0.074)	**0.043, 0.330**	0.245 (0.104)	**0.056, 0.469**
16th = 3.873	-0.604 (0.252)	**-1.166, -0.189**	-0.873 (0.308)	**-1.519, -0.299**
50th = 5.385	-0.347 (0.192)	**-0.777, -0.028**	-0.502 (0.235)	**-0.984, -0.034**
84th = 6.453	-0.166 (0.182)	-0.573, 0.154	-0.240 (0.240)	-0.723, 0.239
	Model A: ln RMSSD MIST (M_1)		Model C: ln PNS Index MIST (M_1)	
Preoccupation with Dieting (*W*)	*b* (*SE*)	95% CI	*b (SE)*	95% CI
ab_3	0.091 (0.064)	-0.032, 0.224	0.105 (0.083)	-0.056, 0.275
16th = 2.000	-0.520 (0.222)	**-1.005, -0.143**	-0.722 (0.268)	**-1.271, -0.224**
50th = 3.464	-0.387 (0.200)	**-0.820, -0.053**	-0.569 (0.247)	**-1.058, -0.083**
84th = 4.829	-0.264 (0.216)	-0.739, 0.100	-0.426 (0.279)	-0.990, 0.119

Note. $N = 97$. CI = Confidence interval; ln RMSSD = Natural logarithm transformed root mean square of successive differences; ln PNS index = Natural logarithm transformed parasympathetic nervous system index. Weight-Focused Restraint and Preoccupation with Dieting reflect square root transformed values. ab_3 = Index of moderated mediation. Bolded 95% CIs do not straddle zero.

Table 6

Indices of Dual Moderated Mediation, SEs, and 95% CIs of PROCESS Model 18 Testing the Effect of MIST Condition (X) on Participant Consumption (Y) through HRV Indices (M) as Moderated by Restraint Factors and Subscales (W) and Frontal Asymmetry (Z)

Restraint Factors and Subscales	ln RMSSD		ln PNS Index	
	ab_7 (*SE*)	95% CI	ab_7 (*SE*)	95% CI
Calorie Counting	0.339 (0.255)	-0.184, 0.858	0.422 (0.363)	-0.312, 1.138
Preocc. with Dieting	0.821 (0.921)	-1.032, 2.653	1.481 (1.150)	-1.069, 3.551
Wt Foc Restraint	1.595 (0.866)	**0.098, 3.546**	2.260 (1.165)	**0.332, 4.977**
EDE-Q-R	1.968 (1.610)	-1.062, 5.378	2.815 (2.194)	-1.365, 7.330
EDI-3-DT	0.735 (0.779)	-0.940, 2.193	1.108 (0.953)	-0.967, 2.826
RS	-0.013 (0.212)	-0.476, 0.396	-0.048 (0.316)	-0.703, 0.606
DEBQ-R	2.814 (1.317)	**0.621, 5.709**	4.179 (1.735)	**1.318, 8.113**
TFEQ-R	0.285 (0.249)	-0.211, 0.800	0.367 (0.342)	-0.286, 1.057

Note. N = 92. Preocc. with Dieting = Preoccupation with Dieting square root transformed; Wt Foc Restraint = Weight-Focused Restraint square root transformed; EDE-Q-R = Eating Disorder Examination-Questionnaire – Restraint subscale square root transformed; EDI-3-DT = Eating Disorder Inventory-3 – Drive for Thinness Scale square root transformed; RS = Revised Restraint Scale; DEBQ-R = Dutch Eating Behaviour Questionnaire – Restrained Eating Scale; TFEQ-R = Three-Factor Eating Questionnaire – Restraint scale; ln RMSSD = Natural logarithm transformed root mean square of successive differences; ln PNS index = Natural logarithm transformed parasympathetic nervous system index. All models control for baseline heart rate variability measures, baseline frontal asymmetry, and average liking of food items. Bolded 95% CIs do not straddle zero.

Table 7

Unstandardized Regression Coefficients, SEs, and 95% CIs of PROCESS Model 18 Estimating Participant Consumption (Y) from MIST Condition (X) through HRV indices (M) as Moderated by Weight-Focused Restraint (W) and Frontal Asymmetry (Z)

	Consequent			
	Model A: ln RMSSD (M_1)		Participant consumption (Y)	
Antecedent	Coeff. (*SE*)	95% CI	Coeff. (*SE*)	95% CI
MIST condition (X)	-0.201** (0.060)	**-0.320, -0.082**	-0.524 (0.501)	-1.520, 0.472
ln RMSSD (M)	--	--	3.685* (1.696)	**0.309, 7.061**
Wt Foc Restraint (W)	--	--	1.111 (1.035)	-0.948, 3.169
$M \times W$	--	--	-0.359 (0.288)	-0.931, 0.213
Frontal asymmetry (Z)	--	--	-160.551* (63.640)	**-287.200, -33.902**
$M \times Z$	--	--	41.494* (17.956)	**5.760, 77.228**
$W \times Z$	--	--	30.341* (11.697)	**7.063, 53.620**
$M \times W \times Z$	--	--	-7.951* (3.230)	**-14.380, -1.523**
Constant	0.438 (0.423)	-0.403, 1.280	-4.134 (5.799)	-15.674, 7.406
	$R^2 = 0.736$		$R^2 = 0.396$	
	$F(4, 87) = 46.686$***		$F(11, 80) = 6.231$***	
	Consequent			
	Model B: ln PNS Index (M_1)		Participant consumption (Y)	
Antecedent	Coeff. (*SE*)	95% CI	Coeff. (*SE*)	95% CI
MIST condition (X)	-0.140*** (0.030)	**-0.199, -0.081**	-0.371 (0.549)	-1.463, 0.722
ln PNS Index (M)	--	--	8.759* (3.789)	**1.218, 16.299**
Wt Foc Restraint (W)	--	--	1.110 (0.906)	-0.693, 2.914
$M \times W$	--	--	-0.906 (0.674)	-2.246, 0.435
Frontal asymmetry (Z)			-131.876** (46.595)	**-224.603, -39.150**
$M \times Z$			85.720* (35.035)	**15.997, 155.442**
$W \times Z$			24.437** (8.983)	**6.561, 42.314**
$M \times W \times Z$			-16.120* (6.575)	**-29.206, -3.035**
Constant	0.099 (0.169)	-0.236, 0.434	-3.877 (4.817)	-13.463, 5.708
	$R^2 = 0.776$		$R^2 = 0.398$	
	$F(4, 87) = 98.074$***		$F(11, 80) = 5.885$***	

Note. $N = 92$. Wt Foc Restraint = Weight-Focused Restraint square root transformed; ln RMSSD = Natural logarithm transformed root mean square of successive differences; ln PNS index = Natural logarithm transformed parasympathetic nervous system index. All models control for baseline heart rate variability measures, baseline frontal asymmetry, and average liking of food items. Bolded 95% CIs do not straddle zero.

*$p < .05$, **$p < .01$, ***$p < .001$

Table 8

Descriptive Statistics of Continuous Dependent Variables and Sample Characteristics by MIST Condition in Study Two

Variables	MIST control condition (n = 50)		MIST stress + certain safety (n = 48)		MIST stress + uncertain safety (n = 49)	
	M (SD)	$z_{skewness}$	M (SD)	$z_{skewness}$	M (SD)	$z_{skewness}$
Age (in years)	24.56 (8.91)	5.34	22.96 (6.32)	6.07	22.39 (6.18)	5.78
BMI	26.46 (6.88)	2.70	24.68 (4.75)	3.98	24.54 (5.73)	3.09
Calorie Counting	7.79 (4.60)	0.25	7.38 (4.68)	0.91	8.34 (5.25)	0.18
Preoccupation with Dieting (sqrt)	3.54 (1.50)	-0.32	3.46 (1.37)	-0.97	3.54 (1.57)	-0.74
Weight-Focused Restraint (sqrt)	5.54 (1.25)	-0.05	5.33 (1.21)	0.90	5.50 (1.34)	-0.13
TFEQ-R	8.67 (5.22)	0.75	8.13 (5.33)	1.46	9.14 (5.79)	0.71
DEBQ-R	2.62 (0.92)	0.53	2.46 (0.85)	1.08	2.55 (0.92)	0.69
EDI-DT (sqrt)	2.64 (1.40)	0.24	2.52 (1.39)	0.35	2.52 (1.67)	-0.37
EDE-Q-R (sqrt)	1.00 (0.66)	-0.01	0.88 (0.65)	1.00	1.01 (0.69)	-0.09
RS	14.55 (7.61)	0.41	13.46 (5.80)	-0.62	13.63 (6.73)	1.24
Baseline ln RMSSD	3.59 (0.58)	0.47	3.69 (0.60)	-0.68	3.50 (0.46)	0.21
Baseline ln PNS Index	1.85 (0.29)	1.54	1.91 (0.32)	0.69	1.80 (0.24)	0.14
Baseline sqrt SNS Index	1.74 (0.35)	0.13	1.62 (0.41)	0.80	1.74 (0.31)	0.06
ln RMSSD during MIST	3.62 (0.53)	0.68	3.45 (0.48)	-0.65	3.40 (0.43)	-1.82
sqrt PNS Index during MIST	1.83 (0.27)	1.86	1.67 (0.27)	-1.00	1.60 (0.28)	-3.29
sqrt SNS Index during MIST	1.68 (0.30)	-0.68	1.85 (0.33)	1.43	1.93 (0.31)	1.37
ln RMSSD during VP	3.64 (0.52)	0.25	3.63 (0.52)	-0.08	3.53 (0.47)	0.22
sqrt PNS Index during VP	1.86 (0.25)	1.77	1.84 (0.29)	1.01	1.77 (0.26)	-1.09
sqrt SNS Index during VP	1.69 (0.32)	-1.00	1.67 (0.39)	0.02	1.79 (0.32)	1.28
AB 100 ms score	-1.58 (13.15)	0.84	-1.48 (13.57)	-0.83	-1.05 (13.13)	0.27
AB 500 ms score	1.73 (16.36)	2.72	-2.49 (13.21)	-1.92	-1.90 (11.80)	-0.72
Overall AB score (sqrt)	5.42 (1.07)	1.31	5.21 (0.98)	-0.84	5.29 (0.92)	-3.21
Food consumption in g (sqrt)	7.89 (1.89)	2.49	7.23 (2.32)	-0.56	6.93 (1.76)	-0.44

Note. N = 147. TFEQ-R = Three-Factor Eating Questionnaire – Restraint scale; DEBQ-R = Dutch Eating Behaviour Questionnaire – Restrained Eating scale; EDI-3-DT = Eating Disorder Inventory-3 – Drive for Thinness scale; EDE-Q-R = Eating Disorder Examination-Questionnaire Restraint scale; RS = Revised Restraint scale; BMI = Body mass index; sqrt = Square root transformed value of variable; ln RMSSD = Natural logarithm transformed root mean square of successive differences; sqrt PNS index = Square root transformed parasympathetic nervous system index; sqrt SNS index = Square root transformed sympathetic nervous system index; MIST = Montreal Imaging Stress Task; AB = Attentional bias.

Table 9

Indices of Serial Mediation, SEs, and 95% Confidence Intervals of PROCESS Model 6 Helmert Coding Testing the Effect of Experimental Condition (X) on Participant Consumption (Y) through HRV Indices (M_1) and Attentional Bias to Food (M_2)

Attentional Bias scores	ln RMSSD		ln PNS Index	
	$a_1d_{21}b_2$ (*SE*)	95% CI	$a_1d_{21}b_2$ (*SE*)	95% CI
AB 100 ms	0.020 (0.018)	-0.005, 0.064	0.021 (0.024)	-0.022, 0.076
AB 500 ms	0.003 (0.010)	-0.012, 0.028	-0.002 (0.014)	-0.030, 0.030
Overall AB (sqrt)	0.023 (0.020)	-0.002, 0.073	0.018 (0.026)	-0.021, 0.083

Note. *N* = 147. AB = Attentional bias; sqrt = Square root transformed values; ln RMSSD = Natural logarithm transformed root mean square of successive differences; sqrt PNS Index = Square root transformed parasympathetic nervous system index. Only $a_1d_{21}b_2$ is reported for hypothesis one given predictions, which reflects the MIST stress + certain safety and MIST stress + uncertain safety conditions grouped together relative to the control condition.

Table 10

Indices of Serial Mediation, SEs, and 95% Confidence Intervals of PROCESS Model 6 Indicator Coding Testing the Effect of Experimental Condition (X) on Participant Consumption (Y) through HRV Indices (M_1) and Attentional Bias to Food (M_2)

		Model A: ln RMSSD (M_1)		Model B: ln PNS Index (M_1)	
AB Score	Relative Indirect Index	*b* (*SE*)	95% CI	*b (SE)*	95% CI
100 ms AB	$a_1d_{21}b_2$	0.024 (0.021)	-0.006, 0.072	0.021 (0.025)	-0.022, 0.078
	$a_2d_{21}b_2$	0.016 (0.016)	-0.004, 0.058	0.021 (0.024)	-0.023, 0.075
500 ms AB	$a_1d_{21}b_2$	0.004 (0.013)	-0.016, 0.036	-0.002 (0.014)	-0.031, 0.031
	$a_2d_{21}b_2$	0.002 (0.008)	-0.010, 0.023	0.002 (0.014)	-0.031, 0.029
Overall AB	$a_1d_{21}b_2$	0.028 (0.024)	-0.003, 0.090	0.018 (0.026)	-0.022, 0.083
	$a_2d_{21}b_2$	0.018 (0.017)	-0.002, 0.062	0.017 (0.025)	-0.023, 0.078

Note. N = 147. AB = Attentional bias; sqrt = Square root transformed values; ln RMSSD = Natural logarithm transformed root mean square of successive differences; sqrt PNS Index = Square root transformed parasympathetic nervous system index. As indicator coding was used, $a_1d_{21}b_2$ reflects the MIST stress + certain safety relative to the control condition and $a_2d_{21}b_2$ reflects the MIST stress + uncertain safety conditions relative to the control condition.

Table 11

Indices of Moderated Serial Mediation, SEs, and 95% CIs of PROCESS Model 91 Indicator Coding Testing the Effect of Condition (X) on Consumption (Y) through HRV (M_1) and Attentional Bias to Food (M_2) as Moderated by Restraint Factors (W)

Preoccupation with Dieting					
		Model A: ln RMSSD (M_1)		Model B: ln PNS Index (M_1)	
AB Score	Relative Indirect Index	*b* (*SE*)	95% CI	*b (SE)*	95% CI
100 ms AB	$a_1d_{21}b_2$	0.006 (0.009)	-0.010, 0.027	0.011 (0.015)	-0.007, 0.050
	$a_2d_{21}b_2$	0.004 (0.007)	-0.007, 0.021	0.011 (0.015)	-0.007, 0.052
500 ms AB	$a_1d_{21}b_2$	-0.001 (0.006)	-0.014, 0.014	-0.008 (0.012)	-0.033, 0.016
	$a_2d_{21}b_2$	-0.001 (0.004)	-0.010, 0.009	-0.008 (0.012)	-0.032, 0.015
Overall AB sqrt	$a_1d_{21}b_2$	0.0003 (0.010)	-0.019, 0.023	-0.006 (0.013)	-0.032, 0.023
	$a_2d_{21}b_2$	0.0002 (0.007)	-0.013, 0.015	-0.006 (0.13)	-0.032, 0.022
Weight Focused Restraint					
		Model A: ln RMSSD (M_1)		Model B: ln PNS Index (M_1)	
AB Score	Relative Indirect Index	*b* (*SE*)	95% CI	*b (SE)*	95% CI
100 ms AB	$a_1d_{21}b_2$	-0.009 (0.013)	-0.038, 0.013	-0.008 (0.017)	-0.044, 0.028
	$a_2d_{21}b_2$	-0.006 (0.009)	-0.029, 0.009	-0.008 (0.017)	-0.045, 0.29
500 ms AB	$a_1d_{21}b_2$	-0.006 (0.011)	-0.032, 0.012	-0.011 (0.017)	-0.051, 0.018
	$a_2d_{21}b_2$	-0.004 (0.007)	-0.022, 0.008	-0.010 (0.016)	-0.049, 0.018
Overall AB sqrt	$a_1d_{21}b_2$	-0.011 (0.014)	-0.044, 0.011	-0.017 (0.019)	-0.060, 0.017
	$a_2d_{21}b_2$	-0.007 (0.010)	-0.031, 0.007	-0.016 (0.019)	-0.060, 0.016
Calorie Counting					
		Model A: ln RMSSD (M_1)		Model B: ln PNS Index (M_1)	
AB Score	Relative Indirect Index	*b* (*SE*)	95% CI	*b (SE)*	95% CI
100 ms AB	$a_1d_{21}b_2$	0.0004 (0.003)	-0.006, 0.007	0.0001 (0.005)	-0.008, 0.011
	$a_2d_{21}b_2$	0.0003 (0.002)	-0.004, 0.005	0.0001 (0.005)	-0.008, 0.011
500 ms AB	$a_1d_{21}b_2$	-0.001 (0.003)	-0.008, 0.004	-0.002 (0.004)	-0.012, 0.005
	$a_2d_{21}b_2$	-0.001 (0.002)	-0.005, 0.003	-0.002 (0.004)	-0.012, 0.004
Overall AB sqrt	$a_1d_{21}b_2$	-0.001 (0.004)	-0.009, 0.006	-0.002 (0.005)	-0.014, 0.008
	$a_2d_{21}b_2$	-0.0004 (0.002)	-0.006, 0.004	-0.002 (0.005)	-0.014, 0.007

Note. N = 147. AB = Attentional bias; sqrt = Square root transformed values; ln RMSSD = Natural logarithm transformed root mean square of successive differences; sqrt PNS Index = Square root transformed parasympathetic nervous system index. As indicator coding was used, $a_1d_{21}b_2$ reflects the MIST stress + certain safety relative to the control condition and $a_2d_{21}b_2$ reflects the MIST stress + uncertain safety conditions relative to the control condition.

Table 12

Indices of Moderated Serial Mediation, SEs, and 95% CIs of PROCESS Model 87 Indicator Coding Testing the Effect of Condition (X) on Participant Consumption (Y) through SNS Index (M_1) and Hunger (M_2) as Moderated by Latent Dietary Restraint Factors and Conventional Restraint Scales (W)

		Model: sqrt SNS index (M_1)	
Latent Restraint Factor	Relative Indirect Index	*b* (*SE*)	95% CI
Preocc. with Dieting	$a_1d_{21}b_2$	0.017 (0.015)	-0.004, 0.054
	$a_2d_{21}b_2$	0.027 (0.017)	**0.002, 0.067**
Wt-Foc Restraint	$a_1d_{21}b_2$	0.018 (0.017)	-0.005, 0.061
	$a_2d_{21}b_2$	0.029 (0.019)	**0.001, 0.074**
Calorie Counting	$a_1d_{21}b_2$	0.004 (0.004)	-0.001, 0.016
	$a_2d_{21}b_2$	0.007 (0.005)	0.000, 0.019
EDE-Q-R	$a_1d_{21}b_2$	0.031 (0.031)	-0.009, 0.108
	$a_2d_{21}b_2$	0.049 (0.034)	**0.001, 0.130**
EDI-3-DT	$a_1d_{21}b_2$	0.013 (0.012)	-0.004, 0.043
	$a_2d_{21}b_2$	0.020 (0.015)	-0.0002, 0.056
RS	$a_1d_{21}b_2$	0.005 (0.004)	-0.001, 0.014
	$a_2d_{21}b_2$	0.007 (0.005)	**0.001, 0.018**
DEBQ-R	$a_1d_{21}b_2$	0.027 (0.025)	-0.006, 0.089
	$a_2d_{21}b_2$	0.042 (0.027)	**0.003, 0.106**
TFEQ-R	$a_1d_{21}b_2$	0.004 (0.004)	-0.001, 0.014
	$a_2d_{21}b_2$	0.006 (0.005)	**0.0001, 0.018**

Note. $N = 147$. sqrt SNS Index = Square root transformed sympathetic nervous system index; Preocc. with Dieting = Preoccupation with Dieting square root transformed; Wt-Foc Restraint = Weight-Focused Restraint square root transformed; EDE-Q-R = Eating Disorder Examination-Questionnaire – Restraint subscale square root transformed; EDI-3-DT = Eating Disorder Inventory-3 – Drive for Thinness Scale square root transformed; RS = Revised Restraint Scale; DEBQ-R = Dutch Eating Behaviour Questionnaire – Restrained Eating Scale; TFEQ-R = Three-Factor Eating Questionnaire – Restraint scale. As indicator coding was used, $a_1d_{21}b_3$ reflects the MIST stress + certain safety relative to the control condition and $a_2d_{21}b_3$ reflects the MIST stress + uncertain safety conditions relative to the control condition. Bolded 95% CIs do not straddle zero.

Table 13

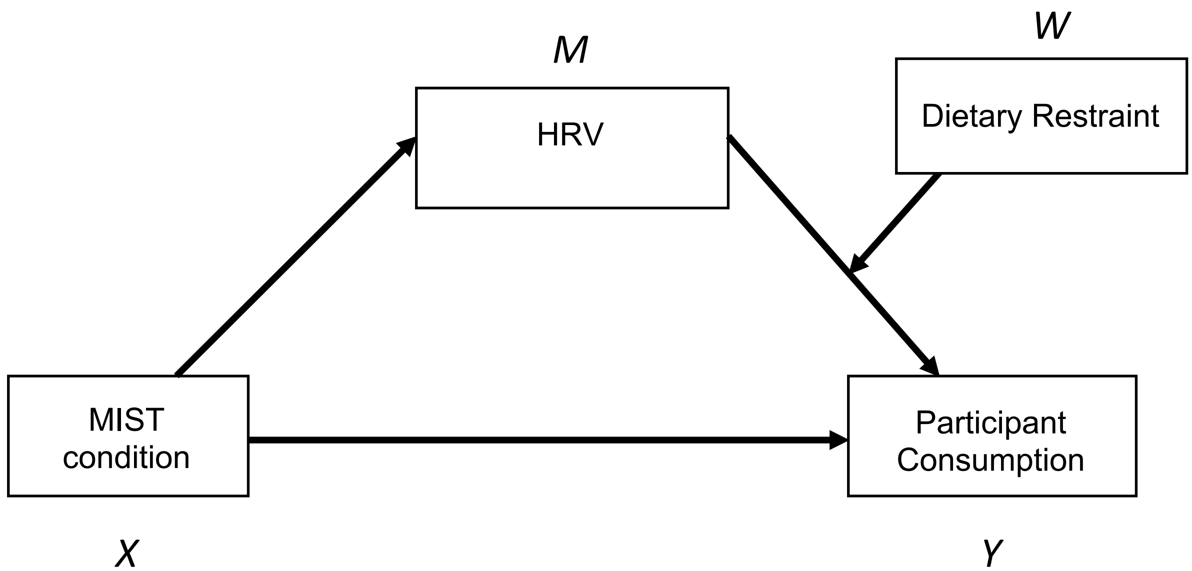
Unstandardized Regression Coefficients, SEs, and 95% CIs Testing the Conditional Indirect Effect of Experimental Condition (X) on Participant Consumption (Y) through SNS Index (M_1) and Hunger (M_2) at Moderating Levels of Preoccupation with Dieting and Weight-Focused Restraint (W)

		sqrt SNS Index (M_1)	
Latent Restraint Factor (*W*)	Values of *W*	*b* (*SE*)	95% CI
Preocc with Dieting	2.236	-0.038 (0.035)	-0.125, 0.009
	3.464	-0.005 (0.026)	-0.064, 0.043
	5.099	0.038 (0.036)	-0.018, 0.122
Wt-Foc Restraint	4.000	-0.051 (0.041)	-0.151, 0.003
	5.385	-0.012 (0.027)	-0.076, 0.036
	6.657	0.025 (0.033)	-0.034, 0.102

Note. Preocc. with Dieting = Preoccupation with Dieting square root transformed; Wt-Foc Restraint = Weight-Focused Restraint square root transformed. Levels of latent restraint factors correspond to the 16^{th}, 50^{th}, and 84^{th} percentiles of dietary restraint, respectively. The conditional indirect effects reported reflect those that accompany $a_2d_{21}b_3$ from model 87.

Figure 1

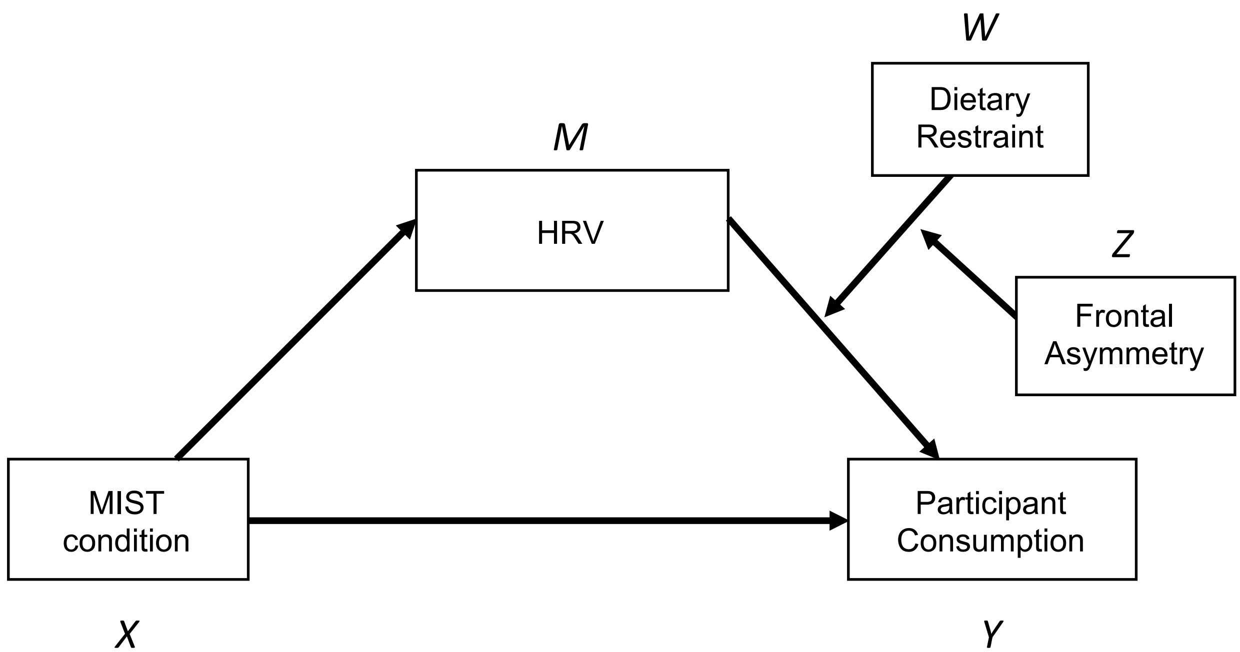
Conceptual Model of Hypothesis One – Study One



Note. MIST = Montreal Imaging Stress Task; HRV = Heart rate variability.

Figure 2

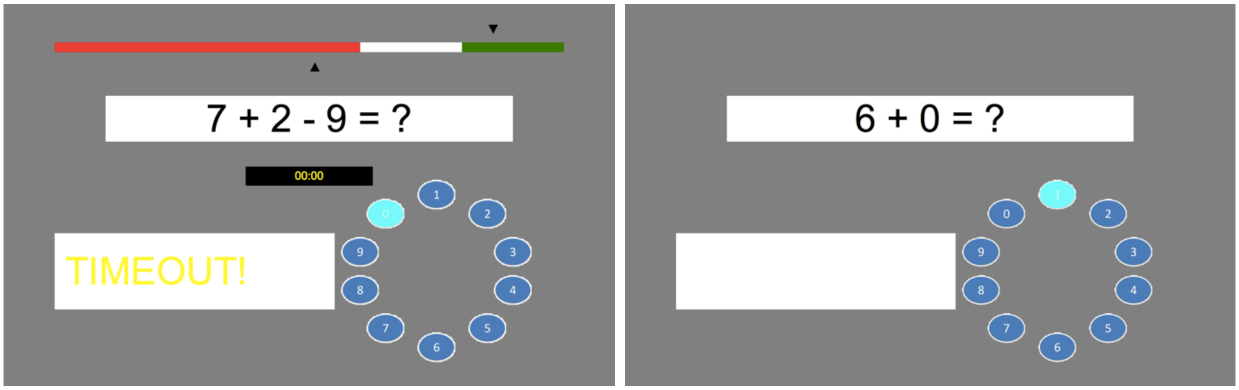
Conceptual Model of Hypothesis Two – Study One



Note. MIST = Montreal Imaging Stress Task; HRV = Heart rate variability.

Figure 3

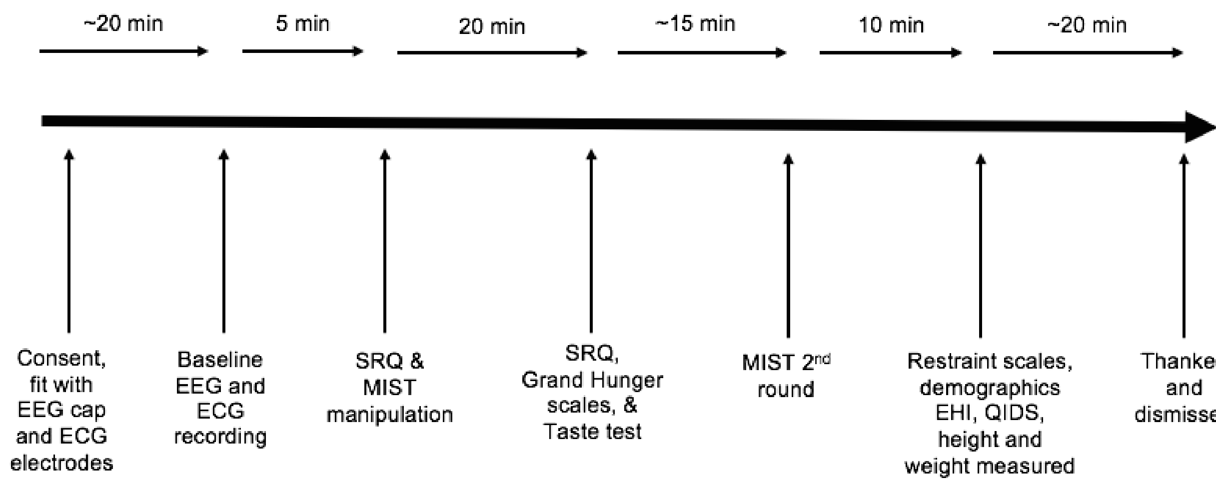
Screenshot of the Montreal Imaging Stress Task Conditions



Note. The stress condition appears on the left and the control condition appears on the right.

Figure 4

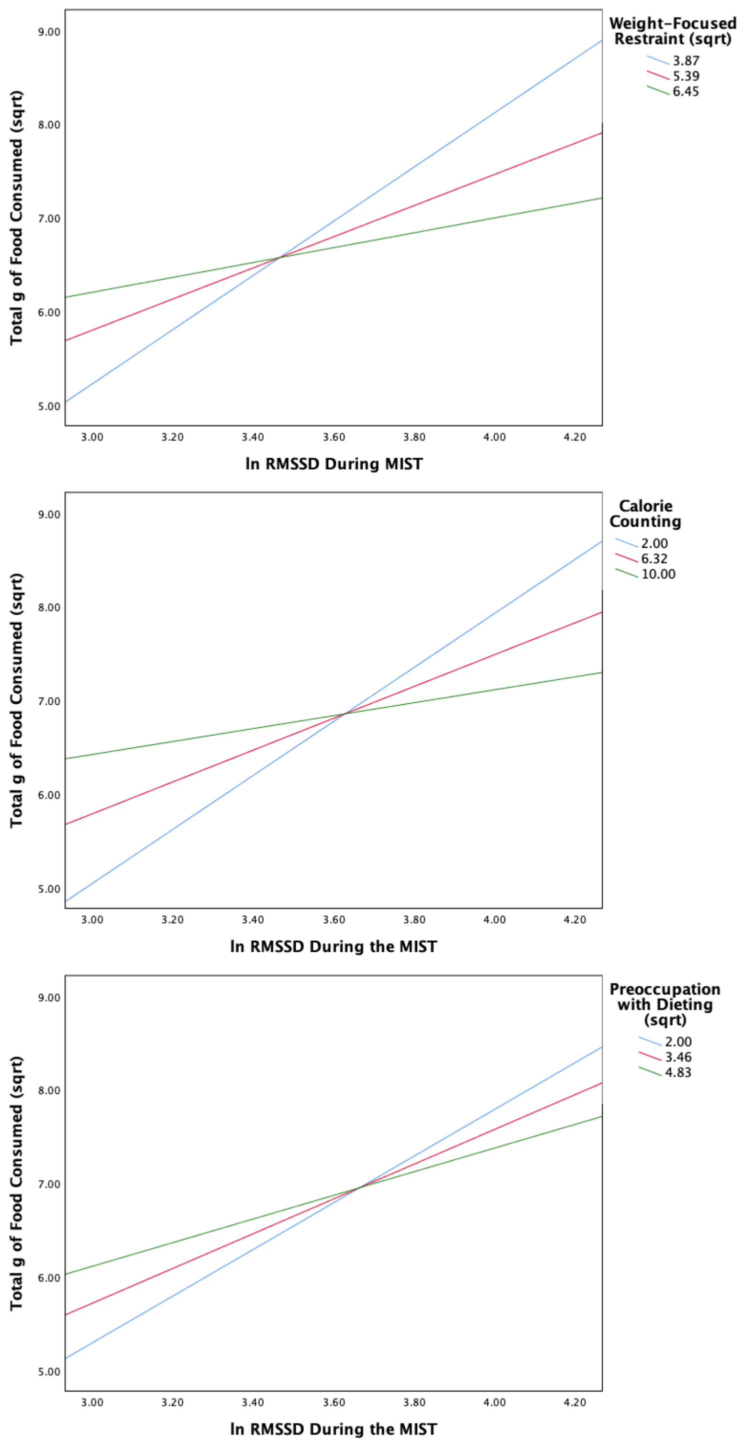
Timeline of Study One Laboratory Protocol



Note. EEG = electroencephalography; ECG = electrocardiogram; SRQ = Stress Rating Questionnaire; MIST = Montreal Imaging Stress Task; EHI = Edinburgh Handedness Inventory; QIDS = Quick Inventory of Depressive Symptomatology.

Figure 5

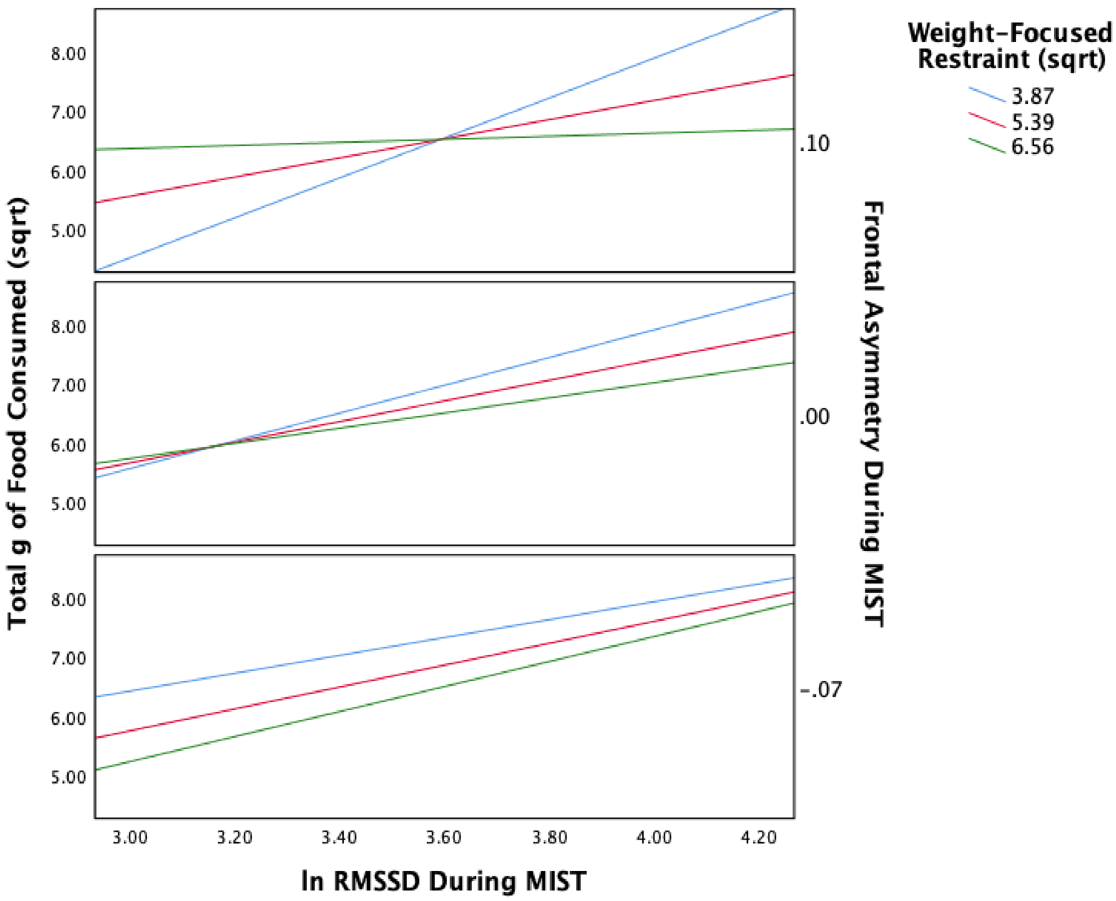
Total g of Food as a Function of ln RMSSD and Hagan et al.'s (2017) Restraint Factors



Note. ln RMSSD = Natural logarithm transformed root mean square of successive differences; MIST = Montreal Imaging Stress Task; sqrt = Square root transformation.

Figure 6

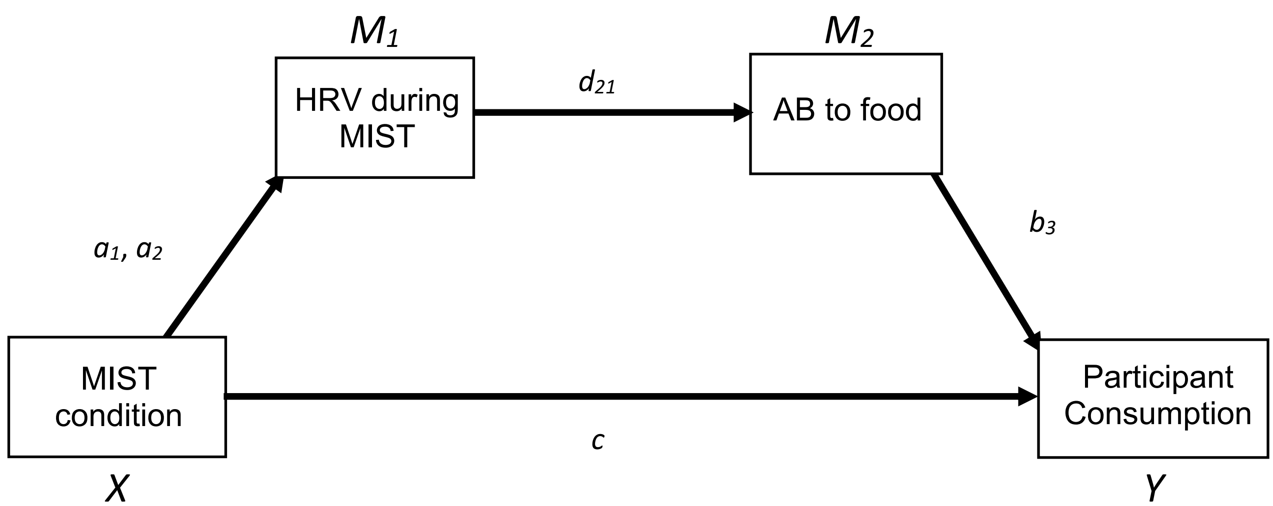
Total g of Food as a Function of ln RMSSD Moderated by Weight-Focused Restraint and Frontal Asymmetry



Note. ln RMSSD = Natural logarithm transformed root mean square of successive differences; MIST = Montreal Imaging Stress Task; sqrt = Square root transformation.

Figure 7

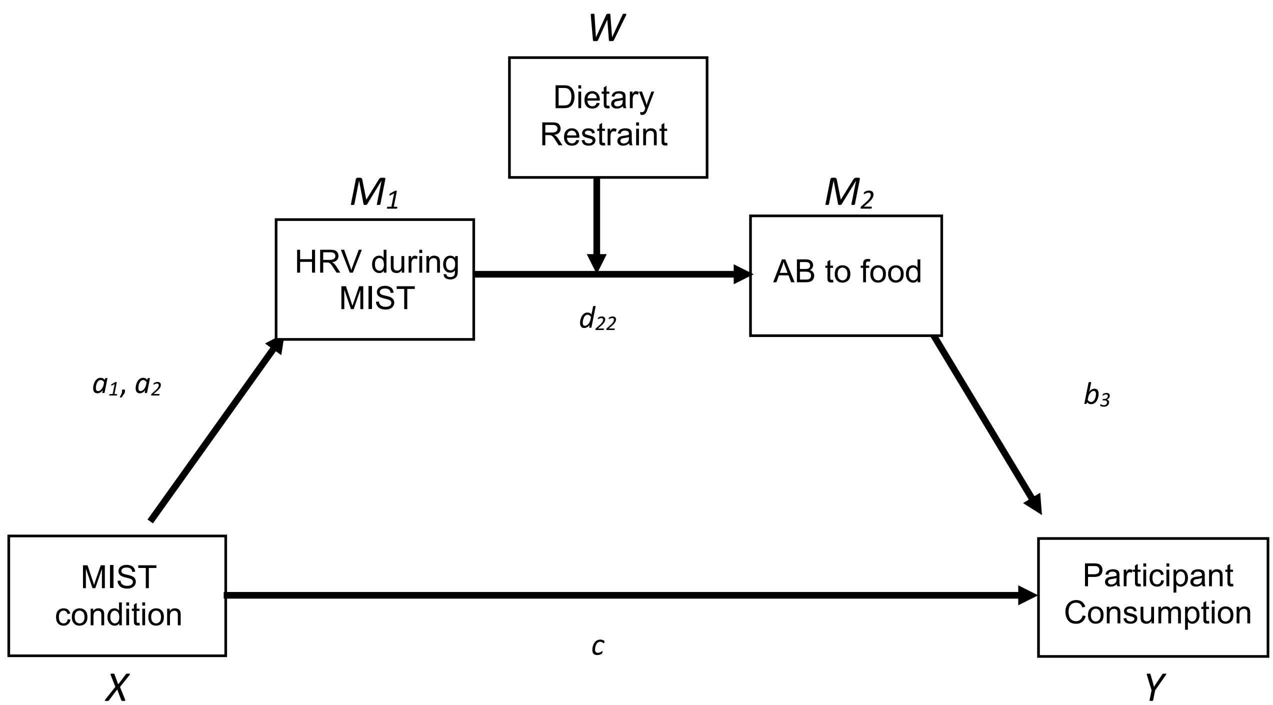
Conceptual Model of Serial Mediation in Study Two



Note. MIST = Montreal Imaging Stress Task; HRV = Heart rate variability; AB = Attentional bias.

Figure 8

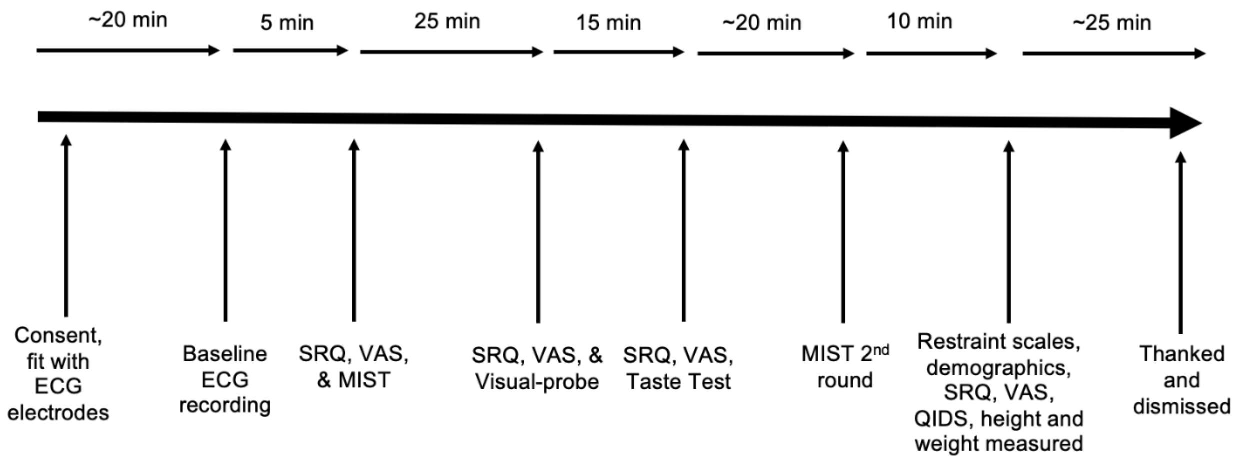
Conceptual Model of Serial Moderated Mediation in Study Two



Note. MIST = Montreal Imaging Stress Task; HRV = Heart rate variability; AB = Attentional bias.

Figure 9

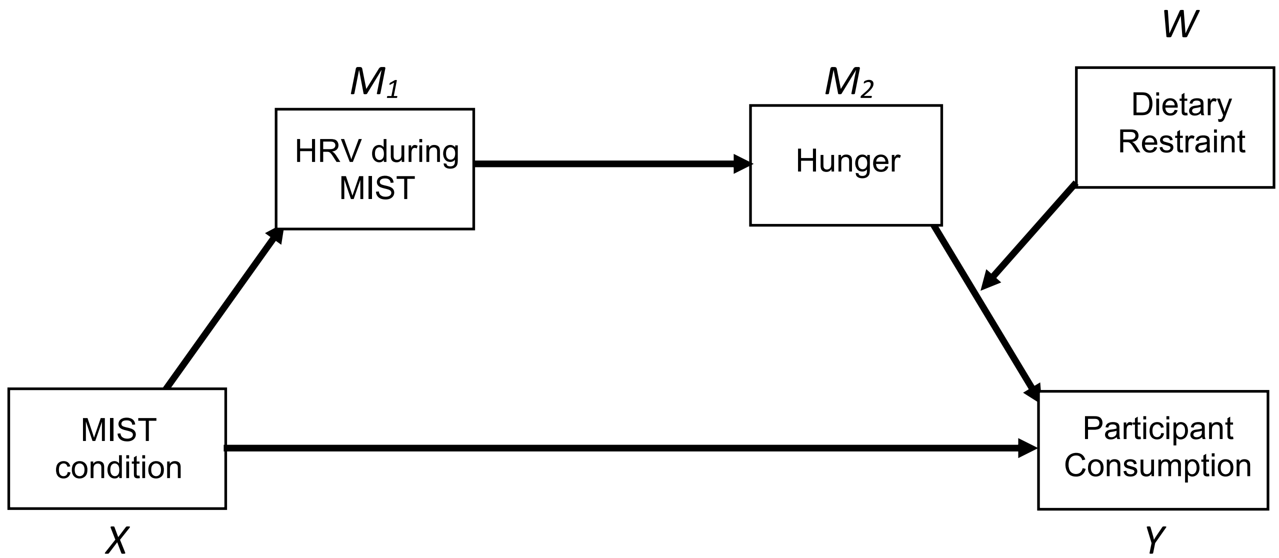
Timeline of Study Two Laboratory Protocol



Note. ECG = electrocardiogram; SRQ = Stress Rating Questionnaire; VAS = Visual analogue scales; MIST = Montreal Imaging Stress Task; QIDS = Quick Inventory of Depressive Symptomatology.

Figure 10

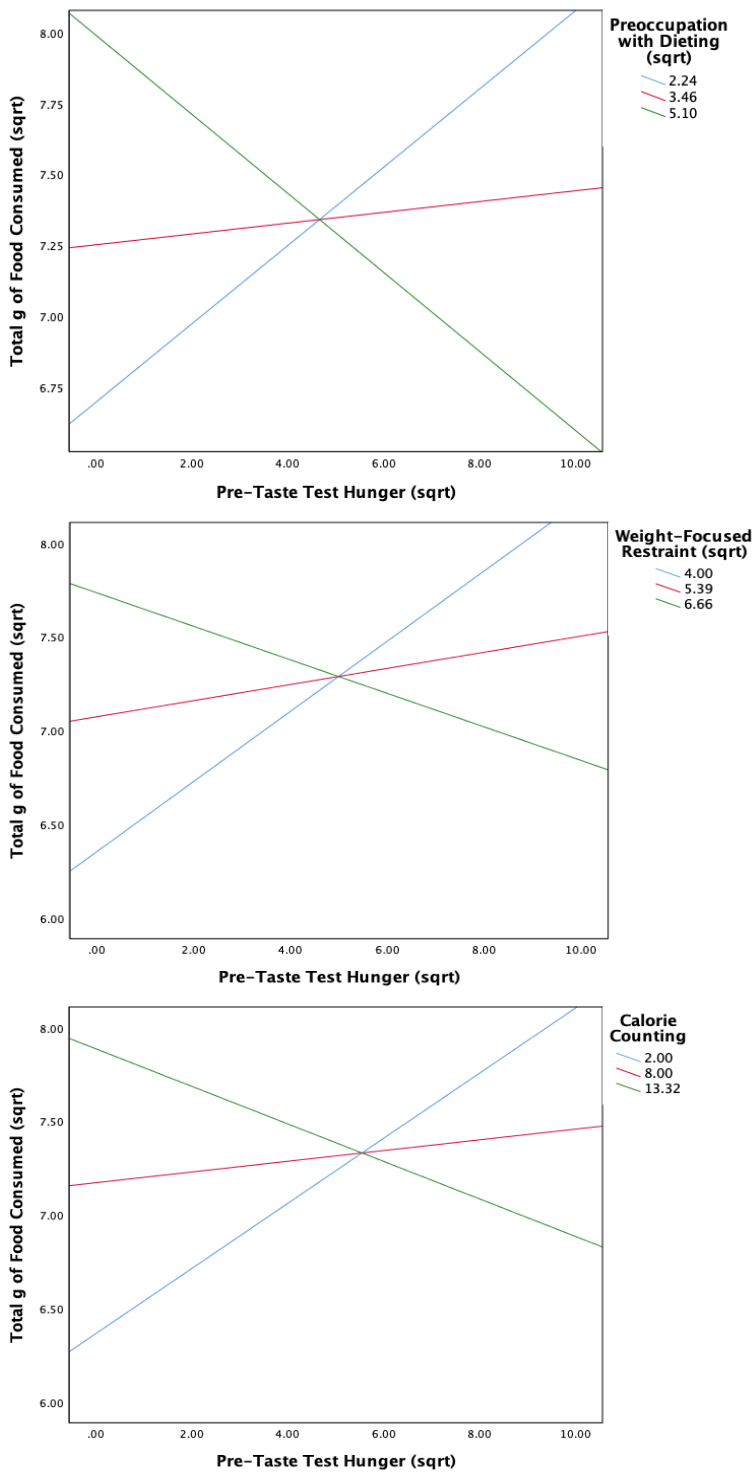
Conceptual Model of Exploratory Hypothesis in Study Two



Note. MIST = Montreal Imaging Stress Task.

Figure 11

Total g of Food as a Function of Hunger Moderated by Hagan et al.'s (2017) Restraint Factors



Note. sqrt = Square root transformation.

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Appendix A
Sona Study Description – Study One

Study Name: Getting to the Heart of Cognition and Sensation study

Description:

You are invited to participate in a research study being conducted by Laura McGeown, a Ph.D. student, and Megan Clark, an undergraduate psychology student, under the supervision of Dr. Ron Davis in the Department of Psychology at Lakehead University. We are examining the relationship between one's heart activity and various sensory and cognitive tasks. We are currently recruiting Lakehead University (Thunder Bay campus) volunteers who are female, age 18 or older, non-smokers, and who usually or always use the right hand for writing, throwing, and holding a spoon and toothbrush from birth to participate in this study. If you choose to participate, you can now sign up to attend a laboratory session over the next week(s) in the Department of Psychology that will take approximately 90 minutes of your time. You must refrain from exercising, caffeine, or eating 2 hours prior to your laboratory session and you must not drink alcohol 24 hours prior, as these activities can interfere with the electroencephalogram (EEG), electrocardiogram (ECG), and electrooculogram (EOG) recordings that will be used to assess electrophysiological activity. Please also ensure you are not currently taking any cold or hypertensive medication for the same reason.

The EEG recording will require that you wear a tight-fitting cap. Be aware that the application of the EEG cap requires a small amount of conductive gel be applied to your scalp. This gel can be easily removed from your hair. You will also be asked to place three electrodes on your chest to record ECG activity. Two electrodes will be placed around your right eye, with one above and one below, to record your visual activity for the EOG recording. During the laboratory session, you will be asked to engage in a working memory task and a sensory perception task while your heart activity is recorded to examine how your heart activity may interact with your performance within each task. Once these tasks are completed, you will be asked to fill out demographics and additional questionnaires. Your height and weight will also be measured, as these variables can affect one's heart activity. As you may be allocated to a taste condition for the sensory perception task, please notify the researcher if you have any food allergies or intolerances. The food items will not contain any nuts, but may include dairy and/or gluten.

Your participation in the study is completely voluntary and you may withdraw at any time, with no penalty. All of the information provided will be kept completely confidential. Only the researchers Laura McGeown and Megan Clark and Dr. Ron Davis will be permitted to view your information. However, Dr. Davis will not be aware of the identities of any students who volunteer to participate in this study. The information you provide will be assigned a code that is unattached to your name and any identifying information provided will be kept confidential in any reports or publications of the results that arise. All of the information provided will be securely stored on a password protected computer located in a double-locked research office in the Department of Psychology at Lakehead University Thunder Bay Campus for 5 years, as per University regulations.

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A risk associated with your participation in this study is the possibility that the act of completing our personal questionnaires may cause an emotional reaction depending upon how you think about yourself in light of the questions you are answering and how you perceive your performance. You may choose not to answer any question asked in the questionnaires without penalty or consequences. If at any point during or after this study you would like to speak to a mental health professional, feel free to contact the Student Health and Counseling Centre located in the Prettie Residence in person or by telephone at 807-343-8361.

If you are registered in a Psychology undergraduate course eligible for bonus points, your participation by way of attending the laboratory visit would lead to 2 bonus points credited to your final grade in that course. Please feel free to contact Laura McGeown at lmcgeown@lakeheadu.ca, Megan Clark at mjclark@lakeheadu.ca, or Dr. Ron Davis at ron.davis@lakeheadu.ca if you have any questions regarding your participation in this study. This study has been approved by the Lakehead University Research Ethics Board. If you have any questions related to the ethics of the research and would like to speak to someone outside of the research team, please contact Sue Wright at the Research Ethics Board at 807-343-8283 or research@lakeheadu.ca

Sincerely,

Laura McGeown lmcgeown@lakeheadu.ca
Megan Clark mjclarke@lakeheadu.ca
Dr. Ron Davis ron.davis@lakeheadu.ca (807) 343-8646

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Appendix B
Participant Information Letter – Study One

Dear Potential Participant:

You have signed up to participate in a research study being conducted by Laura McGeown, a Ph.D. student, and Megan Clark, an undergraduate psychology student, under the supervision of Dr. Ron Davis in the Department of Psychology at Lakehead University. This study is interested in examining the relationship between one's heart activity and various sensory and cognitive tasks. This laboratory session will take approximately 90 minutes of your time.

The EEG recording will require that you wear a tight-fitting cap. Be aware that the application of the EEG cap requires a small amount of conductive gel be applied to your scalp. This gel can be easily removed from your hair. You will also be asked to place three electrodes on your chest to record your heart activity. For your privacy, we will be in the other room while you are applying these electrodes. However, there should be no need for you to remove any of your clothing to apply these electrodes. Two electrodes will be placed around your right eye, with one above and one below, to record your visual activity for the EOG recording. After a baseline recording of your cardiac activity, you will be asked to engage in a working memory task and a sensory perception task while your heart activity is recorded to examine how your heart activity may interact with your performance. Once these tasks are completed, you will be asked to fill out demographic and additional questionnaires. Your height and weight will also be measured, as these variables can affect one's heart activity. As you may be allocated to a taste condition for the sensory perception task, please notify the researcher if you have any food allergies or intolerances. The food items will not contain any nuts, but may include dairy and/or gluten.

Your participation in this study is completely voluntary. You may withdraw your consent at any time, with no penalty. All of the information provided will be kept completely confidential. Only the researchers Laura McGeown and Megan Clark, and Dr. Ron Davis will be permitted to view your information. However, Dr. Davis will never be aware of the identities of any students who participate in this study. The information you provide will be assigned a code that is unattached to your name and any identifying information will be kept confidential in any reports or publications of the results. All information will be securely stored on a password protected computer located in a double-locked research office in the Department of Psychology at Lakehead University Thunder Bay Campus for 5 years, as per University regulations.

A risk associated with your participation in this study is that the act of completing some of the tasks and/or questionnaires may cause an emotional reaction in light of how you perceive your performance and/or the questions. You may choose not to complete any of the tasks or answer any of the questions asked without penalty or consequences. If at any point after this study you would like to speak to a mental health professional, feel free to contact the Student Health and Counselling Centre located in the Prettie Residence in person or by telephone at 807-343-8361.

If you are registered in a Psychology undergraduate course eligible for bonus points, your participation by way of attending the laboratory visit would lead to 2 bonus points credited to your final grade in that course. Please feel free to contact Laura McGeown at lmcgeown@lakeheadu.ca, Megan Clarke at mjclark@lakeheadu.ca, or Dr. Ron Davis at ron.davis@lakeheadu.ca if you have any questions regarding your participation. This study has been approved by the Lakehead University Research Ethics Board. If you have any questions related to the ethics of the research and would like to speak to someone outside of the research team, please contact Sue Wright at the Research Ethics Board at 807-343-8283 or research@lakeheadu.ca.

If you wish to receive a summary of this study's findings, please email Laura McGeown at lmcgeown@lakeheadu.ca and indicate the email address where the results should be sent to. The results will be sent at the conclusion of the study once all analyses have been conducted. You will not be identified directly or indirectly through this process.

Sincerely,

Laura McGeown lmcgeown@lakeheadu.ca
Megan Clark mjclark@lakeheadu.ca
Dr. Ron Davis ron.davis@lakeheadu.ca (807) 343-8646

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Appendix C
Participant Consent Form – Study One

By providing my name and signature below, I indicate that I have read the "Participant Information Letter" and that I have had the opportunity to receive satisfactory answers from the researchers concerning any questions that I might have about my participation in the **Getting to the Heart of Cognition and Sensation study.** I understand and agree to the following:

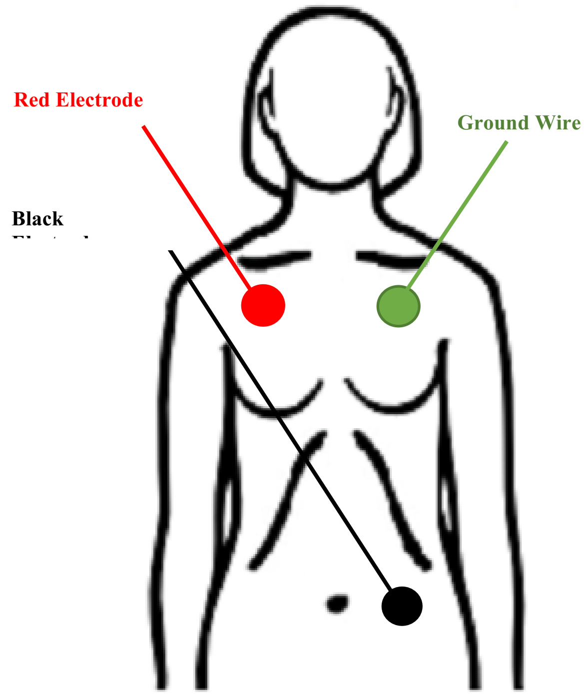
1. I understand all of the information in the "Participant Information Letter";
2. I am a volunteer and can withdraw at any time from this study without penalty or consequence;
3. I may choose not to answer any question asked in the questionnaires without penalty or consequence;
4. I understand that completing some of the questionnaires and tasks may cause an emotional reaction depending on how I think about myself and how I perceive my performance;
5. All information I provide will be kept confidential;
6. My personal information will be securely stored in a double-locked research office in the Department of Psychology at Lakehead University Thunder Bay Campus for 5 years as per University regulations;
7. Dr. Ron Davis is never aware of the identities of those who volunteer to participate in this study;
8. My personal information will remain anonymous should any publications or public presentations come out of this project;
9. I may receive a summary of this research upon completion if I so request;
10. I agree to participate in this study.

____________________________ ____________________________
Full Name (*please print*) Date

____
Signature *(please sign)*

Appendix D
Heart Rate Electrode Placement

As part of this experiment we are interested in collecting information on your heart rate. In order to do this, we will be asking you to place electrodes on your skin in the locations below. There should be no need for you to remove any of your clothing to apply the electrodes.



Please Follow These Steps:

1. Use the alcohol napkin to clean the areas that you will be placing the electrodes.
2. Peel back the protective covering from the black electrode. The surface will now be very sticky, so try not to catch it on your clothes. Place the electrode approximately 1 inch below your collarbone and 2 inches from your right armpit.
3. Peel back the protective covering on the red electrode. Place the electrode below your left ribcage. It sometimes helps to find you lowest left rib with your fingers and then place the electrode approximate 1 inch below this.
4. Peel back the protective covering on the green ground electrode. Place the electrode directly opposite the black electrode on the left side of the body.

This line is 1 inch long

Appendix E
Stress Rating Questionnaire and Perceived Math Ability

Right now, at this moment I feel...

1	2	3	4	5	6	7
Very calm	Quite calm	Slightly calm	Neither calm nor nervous	Slightly nervous	Quite nervous	Very nervous

1	2	3	4	5	6	7
Very fearless	Quite fearless	Slightly fearless	Neither fearless nor fearful	Slightly fearful	Quite fearful	Very fearful

1	2	3	4	5	6	7
Very relaxed	Quite relaxed	Slightly relaxed	Neither relaxed nor anxious	Slightly anxious	Quite anxious	Very anxious

1	2	3	4	5	6	7
Very unconcerned	Quite unconcerned	Slightly unconcerned	Neither unconcerned nor worried	Slightly worried	Quite worried	Very worried

1	2	3	4	5	6	7
Very comfortable	Quite comfortable	Slightly comfortable	Neither comfortable nor tense	Slightly tense	Quite tense	Very tense

I am confident in my ability in mathematics.

0 ———————————————————————— 100

Appendix F
Grand Hunger Scales & Additional Ratings

Please provide an estimate (to the nearest 15 minutes) of the amount of time that has passed since you last ate:

How hungry do you currently feel? Please indicate on the following scale by circling the number in the box that best matches your current level of hunger:

1	2	3	4	5	6	7
Not hungry at all						Extremely hungry

How much of your favourite food would you be able to eat at the present time?

1	2	3	4	5	6
None at all					As much as I could get

Please provide an estimate (to the nearest 15 minutes) of the amount of time until your next expected meal:

How thirsty do you currently feel? Please indicate on the following scale by circling the number in the box that best matches your current level of thirst:

1	2	3	4	5	6	7
Not thirsty at all						Extremely thirsty

How tired do you currently feel? Please indicate on the following scale by circling the number in the box that best matches your current level of fatigue:

1	2	3	4	5	6	7
Not tired at all						Extremely tired

How much discomfort do you currently feel? Please indicate on the following scale by circling the number in the box that best matches your current level of discomfort:

1	2	3	4	5	6	7
None at all						Extreme discomfort

Appendix G
Taste Test Ratings

Please provide your ratings of the food item you have just tasted on the following dimensions. (Note: A separate form will be completed for each food item through SurveyMonkey™).

1. Texture

1	2	3	4	5	6
Strongly disliked					Strongly liked

2. Sweetness

1	2	3	4	5	6
Not sweet at all					Very sweet

3. Crunchiness

1	2	3	4	5	6
Not crunchy at all					Very crunchy

4. Saltiness

1	2	3	4	5	6
Not salty at all					Very salty

5. Overall flavour

1	2	3	4	5	6
Very bland					Very rich

6. I would be likely to eat this as a snack on my own.

1	2	3	4	5	6
Strongly disagree					Strongly agree

7. Please indicate how much you liked this item overall:

1	2	3	4	5	6
Strongly disliked					Strongly liked

Appendix H
Three-Factor Eating Questionnaire

One point is given for each item in Part I and for each item in Part II. The answer for the true/false item that receives a point is underlined. The direction of the question in Part II is determined by splitting the responses at the middle. If the item is labelled "+", those responses above the middle are given a zero. Vice versa for those with a "–". For example, anyone scoring 3 or 4 on the first item in Part II (No. 37) would receive one point. Anyone scoring 1 or 2 would receive a zero. The factor that the item loads onto is indicated by an R for Restraint, D for Disinhibition, and H for Hunger. *Only those items on the Restraint and Disinhibition factors will be administered.*

Part I

1. When I smell a sizzling steak or see a juicy piece of meat, I find it very difficult to keep from eating, even if I have just finished a meal. D	**T**	F
2. I usually eat too much at social occasions, like parties and picnics. D	**T**	F
3. I am usually so hungry that I eat more than three times a day. H	**T**	F
4. When I have eaten my quota of calories, I am usually good about not eating any more. R	**T**	F
5. Dieting is so hard for me because I just get too hungry. H	**T**	F
6. I deliberately take small helpings as a means of controlling my weight. R	**T**	F
7. Sometimes things just taste so good that I keep on eating even when I am no longer hungry. D	**T**	F
8. Since I am often hungry, I sometimes wish that while I am eating, an expert would tell me that I have had enough or that I can have something more to eat. H	**T**	F
9. When I feel anxious, I find myself eating. D	**T**	F
10. Life is too short to worry about dieting. R	T	**F**
11. Since my weight goes up and down, I have gone on reducing diets more than once. D	**T**	F
12. I often feel so hungry that I just have to eat something. H	**T**	F
13. When I am with someone who is overeating, I usually overeat too. D	**T**	F
14. I have a pretty good idea of the number of calories in common food. R	**T**	F
15. Sometimes when I start eating, I just can't seem to stop. D	**T**	F
16. It is not difficult for me to leave something on my plate. D	T	**F**
17. At certain times of the day, I get hungry because I have gotten used to eating then. H	**T**	F
18. While on a diet, if I eat food that is not allowed, I consciously eat less for a period of time to make up for it. R	**T**	F
19. Being with someone who is eating often makes me hungry enough to eat also. H	**T**	F
20. When I feel blue, I often overeat. D	**T**	F
21. I enjoy eating too much to spoil it by counting calories or watching my weight. R	T	**F**
22. When I see a real delicacy, I often get so hungry that I have to eat right away. H	**T**	F

23. I often stop eating when I am not really full as a conscious means of limiting the amount that I eat. R	**<u>T</u>**	**F**
24. I get so hungry that my stomach often seems like a bottomless pit. H	**<u>T</u>**	**F**
25. My weight has hardly changed at all in the last ten years. D	**T**	**<u>F</u>**
26. I am always hungry so it is hard for me to stop eating before I finish the food on my plate. H	**<u>T</u>**	**F**
27. When I feel lonely, I console myself by eating. D	**<u>T</u>**	**F**
28. I consciously hold back at meals in order not to gain weight. R	**<u>T</u>**	**F**
29. I sometimes get very hungry late in the evening or at night. H	**<u>T</u>**	**F**
30. I eat anything I want, any time I want. R	**T**	**<u>F</u>**
31. Without even thinking about it, I take a long time to eat. D	**T**	**<u>F</u>**
32. I count calories as a conscious means of controlling my weight. R	**<u>T</u>**	**F**
33. I do not eat some foods because they make me fat. R	**<u>T</u>**	**F**
34. I am always hungry enough to eat at any time. H	**<u>T</u>**	**F**
35. I pay a great deal of attention to changes in my figure. R	**<u>T</u>**	**F**
36. While on a diet, if I eat a food that is not allowed, I often then splurge and eat other high calories foods. D	**<u>T</u>**	**F**

Part II

Directions: Please answer the following questions by circling the number above the response that is appropriate to you.

37. How often are you dieting in a conscious effort to control your weight? + R

1	2	3	4
Rarely	Sometimes	Usually	Always

38. Would a weight fluctuation of 5 lbs affect the way you live your life? + R

1	2	3	4
Not at all	Slightly	Moderately	Very Much

39. How often do you feel hungry? + H

1	2	3	4
Only at mealtimes	Sometimes between mealtimes	Often between mealtimes	Almost always

40. Do your feelings of guilt about overeating help you to control your food intake? + R

1	2	3	4
Never	Rarely	Often	Always

41. How difficult would it be for you to stop eating halfway through dinner and not eat for the next four hours? + H

1	2	3	4
Easy	Slightly difficult	Moderately difficult	Very difficult

42. How conscious are you of what you are eating? + R

1	2	3	4
Not at all	Slightly	Moderately	Extremely

43. How frequently do you avoid ‘stocking up’ on tempting foods? + R

1	2	3	4
Almost never	Seldom	Usually	Almost always

44. How likely are you to shop for low calorie foods? + R

1	2	3	4
Unlikely	Slightly unlikely	Moderately likely	Very likely

45. Do you eat sensibly in front of others and splurge alone? + D

1	2	3	4
Never	Rarely	Often	Always

46. How likely are you to consciously eat slowly in order to cut down on how much you eat? + R

1	2	3	4
Unlikely	Slightly likely	Moderately likely	Very likely

47. How frequently do you skip dessert because you are no longer hungry? - H

1	2	3	4
Almost never	Seldom	At least once a week	Almost every day

48. How likely are you to consciously eat less than you want? + R

1	2	3	4
Unlikely	Slightly likely	Moderately likely	Very likely

49. Do you go on eating binges though you are not hungry? + D

1	2	3	4
Never	Rarely	Sometimes	At least once a week

50. On a scale of 0 to 5, where 0 means no restraint in eating (eating whatever you want, whenever you want it) and 5 means total restraint (constantly limiting food intake and never 'giving in'), what number would you give yourself? + R

- ☐ Eat whatever you want, whenever you want it
- ☐ Usually eat whatever you want, whenever you want it
- ☐ Often eat whatever you want, whenever you want it
- ☐ Often limit food intake, but often 'give in'
- ☐ Usually limit food intake, rarely 'give in'
- ☐ Constantly limiting food intake, never 'giving in'

51. To what extent does this statement describe your eating behaviour? 'I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising myself to start dieting again tomorrow.' + D

1	2	3	4
Not like me	Little like me	Pretty good description of me	Describes me perfectly

Appendix I
Dutch Eating Behavior Questionnaire – Restrained Eating scale

Items are responded to on a 5-point Likert scale response format, where 1 (*never*), 2 (*seldom*), 3 (*sometimes*), 4 (*often*), and 5 (*very often*).

Restrained Eating items

1. If you have put on weight, do you eat less than you usually do?
2. Do you try to eat less at meal times than you would like to eat?
3. How often do you refuse food or drink offered because you are concerned about your weight?
4. Do you watch exactly what you eat?
5. Do you deliberately eat food that are slimming?
6. When you have eaten too much, do you eat less than usual the following day?
7. Do you deliberately eat less in order not to become heavier?
8. How often do you try not to eat between meals because you are watching your weight?
9. How often in the evenings do you try not to eat because you are watching your weight?
10. Do you take into account your weight with what you eat?

Appendix J
Revised Restraint Scale

1. How many pounds over your desired weight were you at your maximum weight? _______ (Score: 1 point/5 pounds)

2. How often are you dieting?

Rarely	Sometimes	Usually	Always
1	2	3	4

3. Which best describes your behavior after you have eaten a "not allowed" food while on your diet? (Score: 0-2)

- ☐ Return to diet
- ☐ Stop eating for an extended period of time in order to compensate
- ☐ Continue on a splurge, eating other "not allowed" foods

4. What is the maximum amount of weight that you have ever lost within 1 month? _______ (Score: 1 point/5 pounds)

5. What is your maximum weight gain within a week? _______ (Score: 1 point/3 pounds)

6. In a typical week, how much does your weight fluctuate (maximum-minimum)? _______ (Score: 1 point/3 pounds)

7. Would a weight fluctuation of 5 pounds affect the way you live your life?

Not at all	Slightly	Moderately	Very Much
0	1	2	3

8. Do you eat sensibly before others and make up for it alone?

Never	Rarely	Often	Always
0	1	2	3

9. Do you give too much time and thought to food?

Never	Rarely	Often	Always
0	1	2	3

10. Do you have feelings of guilt after overeating?

Never	Rarely	Often	Always
0	1	2	3

11. How conscious are you of what you're eating?

Not at all	Slightly	Moderately	Extremely
0	1	2	3

Appendix K
Eating Disorder Examination-Questionnaire – Restraint subscale

Instructions
The following questions are concerned with the **PAST FOUR WEEKS ONLY** (**28 DAYS**). Please read each question carefully and circle the number on the right. Please answer ALL the questions.

EXAMPLES: **ON HOW MANY DAYS OUT OF THE PAST 28 DAYS…….**	No days	1-5 days	6-12 days	13-15 days	16-22 days	23-27 days	Every day
…Have you tried to eat vegetables?	0	1	2	(3)	4	5	6
…How many times have you walked to school?	0	1	(2)	3	4	5	6

ON HOW MANY DAYS OUT OF THE PAST 28 DAYS…..	No days	1-5 days	6-12 days	13-15 days	16-22 days	23-27 days	Every day
1. …Have you been deliberately trying to limit the amount of food you eat to influence your shape or weight?	0	1	2	3	4	5	6
2. …Have you gone for long periods of time (8 hrs or more) without eating anything in order to influence your shape or weight?	0	1	2	3	4	5	6
3. …Have you tried to avoid eating any foods which you like in order to influence your shape or weight?	0	1	2	3	4	5	6
4. …Have you ever tried to follow definite rules regarding your eating in order to influence your shape or weight; for example, a calorie limit, a set amount of food, or rules about what or when you should eat?	0	1	2	3	4	5	6
5. …Have you wanted your stomach to be empty?	0	1	2	3	4	5	6

Appendix L
Eating Disorder Inventory–3: Drive for Thinness Scale

1. I eat sweets and carbohydrates without feeling nervous.

Always	Usually	Often	Sometimes	Rarely	Never
0	0	1	2	3	4

2. I think about dieting.

Always	Usually	Often	Sometimes	Rarely	Never
4	3	2	1	0	0

3. I feel extremely guilty after overeating.

Always	Usually	Often	Sometimes	Rarely	Never
4	3	2	1	0	0

4. I am terrified of gaining weight.

Always	Usually	Often	Sometimes	Rarely	Never
4	3	2	1	0	0

5. I exaggerate or magnify the importance of weight.

Always	Usually	Often	Sometimes	Rarely	Never
4	3	2	1	0	0

6. I am preoccupied with the desire to be thinner.

Always	Usually	Often	Sometimes	Rarely	Never
4	3	2	1	0	0

7. If I gain a pound, I worry that I will keep gaining.

Always	Usually	Often	Sometimes	Rarely	Never
4	3	2	1	0	0

Appendix M
Demographics Questionnaire – Study One

Age: _________

Marital Status (please circle one below):

Married/Common law Divorced/Separated Single Widowed

Ethnicity (please check one or indicate below)

_____ Caucasian/White

_____ Aboriginal/First Nation

_____ South Asian

_____ Hispanic

_____ African-Canadian/Black

_____ East Asian

_____ Middle Eastern

_____ Other (please identify): ___________________

School Enrolment (please circle one)

Full time Part time Not enrolled

What subject are you majoring in? ___________________

Please list the name(s) of prescribed medication(s) and/or over-the-counter medications you are currently taking:

Please check the box if you are currently taking some form of hormonal birth control. ☐

Please indicate the number of days since the first day of your last menstrual cycle: _______

Please indicate if you have any dietary restrictions (i.e. vegan, vegetarian, food allergies/intolerances):

Appendix N
Edinburgh Handedness Inventory – Short Form

Please indicate your preference in the use of hands in the following activities or objects:

0 = Always Right; 1 = Usually Right; 3 = Both Equally; 4 = Usually Left; 5 = Always Left

1. Writing	0	1	2	3	4
2. Throwing	0	1	2	3	4
3. Toothbrush	0	1	2	3	4
4. Spoon	0	1	2	3	4

Appendix O
Quick Inventory of Depressive Symptomatology – Self-Report

Please mark the one response to each item that is most appropriate to how you have been feeling over the past 7 days.

1. **Falling asleep:**
- I never took longer than 30 minutes to fall asleep.
- I took at least 30 minutes to fall asleep, less than half the time (3 days or less out of the past 7 days).
- I took at least 30 minutes to fall asleep, more than half the time (4 days or more out of the past 7 days).
- I took more than 60 minutes to fall asleep, more than half the time (4 days or more out of the past 7 days).

2. **Sleep during the night:**
- I didn't wake up at night.
- I had a restless, light sleep, briefly waking up a few times each night.
- I woke up at least once a night, but I got back to sleep easily.
- I woke up more than once a night and stayed awake for 20 minutes or more, more than half the time (4 days or more out of the past 7 days).

3. **Waking up too early:**
- Most of the time, I woke up no more than 30 minutes before my scheduled time.
- More than half the time (4 days or more out of the past 7 days), I woke up more than 30 minutes before my scheduled time.
- I almost always woke up at least one hour or so before my scheduled time, but I got back to sleep eventually.
- I woke up at least one hour before my scheduled time, and couldn't get back to sleep.

4. **Sleeping too much:**
- I slept no longer than 7-8 hours/night, without napping during the day.
- I slept no longer than 10 hours in a 24-hour period including naps.
- I slept no longer than 12 hours in a 24-hour period including naps.
- I slept longer than 12 hours in a 24-hour period including naps.

5. **Feeling sad:**
- I didn't feel sad.
- I felt sad less than half the time (3 days or less out of the past 7 days).
- I felt sad more than half the time (4 days or more out of the past 7 days).
- I felt sad nearly all the time.

Please complete <u>either</u> 6 <u>or</u> 7 (not both)

6. Decreased appetite:
- ☐ There was no change in my usual appetite.
- ☐ I ate somewhat less often or smaller amounts of food than usual.
- ☐ I ate much less than usual and only by forcing myself to eat.
- ☐ I rarely ate within a 24-hour period, and only by really forcing myself to eat or when others persuaded me to eat.

7. Increased appetite:
- ☐ There was no change in my usual appetite.
- ☐ I felt a need to eat more frequently than usual.
- ☐ I regularly ate more often and/or greater amounts of food than usual.
- ☐ I felt driven to overeat both at mealtime and between meals.

Please complete <u>either</u> 8 <u>or</u> 9 (not both)

8. Decreased weight (within the last 14 days):
- ☐ My weight has not changed.
- ☐ I feel as if I've had a slight weight loss.
- ☐ I've lost 2 pounds (about 1 kilo) or more.
- ☐ I've lost 5 pounds (about 2 kilos) or more.

9. Increased weight (within the last 14 days):
- ☐ My weight has not changed.
- ☐ I feel as if I've had a slight weight gain.
- ☐ I've gained 2 pounds (about 1 kilo) or more.
- ☐ I've gained 5 pounds (about 2 kilos) or more.

10. Concentration/decision-making:
- ☐ There was no change in my usual ability to concentrate or make decisions.
- ☐ I occasionally felt indecisive or found that my attention wandered.
- ☐ Most of the time, I found it hard to focus or to make decisions.
- ☐ I couldn't concentrate well enough to read or I couldn't make even minor decisions.

11. Perception of myself:
- ☐ I saw myself as equally worthwhile and deserving as other people.
- ☐ I put the blame on myself more than usual.
- ☐ For the most part, I believed that I caused problems for others.
- ☐ I thought almost constantly about major and minor defects in myself.

12. Thoughts of my own death or suicide:
- ☐ I didn't think of suicide or death.
- ☐ I felt that life was empty or wondered if it was worth living.
- ☐ I thought of suicide or death several times for several minutes over the past 7 days.
- ☐ I thought of suicide or death several times a day in some detail, or I made specific plans for suicide or actually tried to take my life.

13. General interest:
- ☐ There was no change from usual in how interested I was in other people or activities.
- ☐ I noticed that I was less interested in other people or activities.
- ☐ I found I had interest in only one or two of the activities I used to do.
- ☐ I had virtually no interest in the activities I used to do.

14. Energy level:
- ☐ There was no change in my usual level of energy.
- ☐ I got tired more easily than usual.
- ☐ I had to make a big effort to start or finish my usual daily activities (for example: shopping, homework, cooking or going to work).
- ☐ I really couldn't carry out most of my usual daily activities because I just didn't have the energy.

15. Feeling more sluggish than usual:
- ☐ I thought, spoke, and moved at my usual pace.
- ☐ I found that my thinking was more sluggish than usual or my voice sounded dull or flat.
- ☐ It took me several seconds to respond to most questions and I was sure my thinking was more sluggish than usual.
- ☐ I was often unable to respond to questions without forcing myself.

16. Feeling restless (agitated, not relaxed, fidgety):
- ☐ I didn't feel restless.
- ☐ I was often fidgety, wringing my hands, or needed to change my sitting position.
- ☐ I had sudden urges to move about and was quite restless.
- ☐ At times, I was unable to stay seated and needed to pace around.

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Appendix P
Participant Debriefing Email – Study One

Dear Participant:

Thank you again for your participation in the study entitled, "Getting to the Heart of Cognition and Sensation study." We purposefully did not explain the true purpose of the study at the time of your participation. It was explained that the purpose of the study was to examine the relationship between one's heart activity and various sensory and cognitive tasks. Although it is true that we were examining your cardiac responses to these tasks, the true purpose of the study was to examine how your heart activity in response to stress may have predicted later food consumption during the supposed "taste perception" task, which was not randomly selected as indicated. All participants completed this taste test task.

This deception was done for multiple reasons. Firstly, previous studies have shown that individuals may alter their eating behaviour when they know that it is under scrutiny in a laboratory situation. More generally, when the predicted response is clearly stated, it is possible that some individuals participating in a study may not act naturally and may be influenced by perceptions of the experimenters' expectations. Therefore, to properly address the research question and ensure valid results were obtained, it was necessary to include deception about the purpose of this study.

In one group, the "working memory" task was presented in a highly stressful manner. The arithmetic problems were timed so that the time limit would be 10% less than the average time it took to respond to the training items. The time limit also decreased if three correct answers were provided in a row. This was done to induce a high failure rate. For those in this condition, the researcher also added additional stress in between each block of items by comparing your performance to the "average." If you were in this condition, the researcher later told you that they had pressed a wrong button after the taste test. This was done to reduce the risk that you would feel poorly about your performance, since the task had been designed to be beyond your mental capacity. For those in the control condition, you would have simply completed a number of arithmetic problems without additional stress from the researcher or a set time limit. The second round of the task was included to account for the second round completed by those in the stressful condition to ensure an equal time commitment in the laboratory.

Please feel free to contact Laura McGeown and/or Dr. Ron Davis if you have any concerns or questions about your participation or the study in light of this disclosure, and we will be happy to answer any questions you may have. If you have any questions related to the ethics of this study or your rights as a research participant and would like to speak to someone outside of the research team, please contact Sue Wright at the Research Ethics Board at 807-343-8283 or research@lakeheadu.ca. Your participation in this study is greatly appreciated. We hope that you found your participation in this study an interesting and valuable experience.

Sincerely,
Laura McGeown lmcgeown@lakeheadu.ca
Dr. Ron Davis ron.davis@lakeheadu.ca (807) 343-8646

Appendix Q
Sona Study Description – Study Two

Study Name: Coming from the Heart: The Role of Heart Activity in Cognition and Perception

Description:

You are invited to participate in a research study being conducted by Laura McGeown, a Ph.D. student, under the supervision of Dr. Ron Davis in the Department of Psychology at Lakehead University. We are examining the relationship between one's heart activity, cognitive abilities, and sensory perception. We are currently recruiting Lakehead University (Thunder Bay campus) volunteers who are female, age 18 or older, non-smokers, and who usually or always use the right hand for writing, throwing, and holding a spoon and toothbrush from birth to participate in this study. If you choose to participate, you can now sign up to attend a laboratory session over the next week(s) in the Department of Psychology that will take approximately 120 minutes of your time. You must refrain from exercising, caffeine, or eating 2 hours prior to your laboratory session and you must not drink alcohol 24 hours prior, as these activities can interfere with the electroencephalogram (EEG), electrocardiogram (ECG), and electrooculogram (EOG) recordings that will be used to assess electrophysiological activity. Please also ensure you are not currently taking any cold or hypertensive medication for the same reason.

The EEG recording will require that you wear a tight-fitting cap. Be aware that the application of the EEG cap requires a small amount of conductive gel be applied to your scalp. This gel can be easily removed from your hair. You will also be asked to place three electrodes on your chest to record ECG activity. Two electrodes will be placed around your right eye, with one above and one below, to record your visual activity for the EOG recording. During the laboratory session, you will be asked to engage in a working memory task and a sensory perception task while your heart activity is recorded to examine how your heart activity may interact with your performance within each task. Once these tasks are completed, you will be asked to fill out demographics and additional questionnaires. Your height and weight will also be measured, as these variables can affect one's heart activity. As you may be allocated to a taste condition for the sensory perception task, please notify the researcher if you have any food allergies or intolerances. The food items will not contain any nuts, but may include dairy and/or gluten.

Your participation in the study is completely voluntary and you may withdraw at any time, with no penalty. All of the information provided will be kept completely confidential. Only the researcher, Laura McGeown, and research supervisor, Dr. Ron Davis, will be permitted to view your data. However, Dr. Davis is never made aware of the identities of any students who volunteer to participate in this study. The information you provide will be assigned a code that is unattached to your name, and he will only be permitted to view the data from the study once it has been anonymized. In this way, it is ensured that your participation will not lead to any biases for or against you if you are currently enrolled in any of his courses. Any identifying information will be kept confidential in any reports or publications of the results. All of the information provided will be securely stored on a password protected computer located in a double-locked research office in the Department of Psychology at Lakehead University Thunder Bay Campus

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for 5 years, as per University regulations.

A risk associated with your participation in this study is the possibility that the act of completing our personal questionnaires may cause an emotional reaction depending upon how you think about yourself in light of the questions you are answering and how you perceive your performance. You may choose not to answer any question asked in the questionnaires without penalty or consequences. If at any point during or after this study you would like to speak to a mental health professional, feel free to contact the Student Health and Counseling Centre located in the Prettie Residence in person or by telephone at 807-343-8361.

If you are registered in a Psychology undergraduate course eligible for bonus points, your participation by way of attending the laboratory visit would lead to 2.5 bonus points credited to your final grade in that course. You will also receive a $10 token honorarium to thank you for your participation. Please feel free to contact Laura McGeown at lmcgeown@lakeheadu.ca or Dr. Ron Davis at ron.davis@lakeheadu.ca if you have any questions regarding your participation in this study. This study has been approved by the Lakehead University Research Ethics Board. If you have any questions related to the ethics of the research and would like to speak to someone outside of the research team, please contact Sue Wright at the Research Ethics Board at 807-343-8283 or research@lakeheadu.ca

Sincerely,

Laura McGeown lmcgeown@lakeheadu.ca
Dr. Ron Davis ron.davis@lakeheadu.ca (807) 343-8646

Appendix R
Graduate Student Email Advertisement – Study Two

Hi there fellow graduate students!

My name is Laura McGeown, and I'm a third year Ph.D. student in the Clinical Psychology program here at Lakehead University. I'm currently recruiting female participants for the final study of my dissertation entitled the **Coming from the Heart study**! We are examining how individuals' heart activity is related to their cognitive skills and sensory perception.

Each participant who participates will receive $10! If you are enrolled in an undergraduate psychology course that is eligible for bonus points, you will also receive 2.5 bonus points!

The study would take 2 hours of your time and would involve the completion of a working memory task, reaction time task, and sensory perception task while your heart, brain, and visual activity are recorded, followed by the completion of a few questionnaires. While participating, you would be fitted with an EEG cap to measure your brain activity and some electrodes to record your heart and visual activity.

Participants must be female and 18 years of age and older. You must also be a non-smoker, right-handed, and not taking any cold, hypertensive, or antidepressant medication.

If you are interested in participating or would like more information, please feel free to contact Laura McGeown at lmcgeown@lakeheadu.ca!

Appendix S
Poster Advertisement – Study Two

Appendix T
Visual Analogue Scales

Please indicate your current physical and emotional state on the following variables before the next recording of your heart and brain activity by dragging the mouse cursor to the appropriate position on the line.

1) How tired do you currently feel?

0 — 100
Not tired at all — Extremely tired

2) How much discomfort do you currently feel?

0 — 100
No discomfort at all — Extreme discomfort

3) How thirsty do you currently feel?

0 — 100
Not thirsty at all — Extremely thirsty

4) How hungry do you currently feel?

0 — 100
Not at all hungry — Extremely hungry

5) How safe do you currently feel?

0 — 100
Not at all safe — Extremely safe

6) How secure do you currently feel?

0 — 100
Not at all secure — Extremely secure

7) How content do you currently feel?

0 — 100
Not at all content — Extremely content

8) How warm do you currently feel?

0 — 100
Not at all warm — Extremely warm

Appendix U
Demographics Questionnaire – Study Two

Age: _________

Marital Status (please circle one below):

Married/Common law Divorced/Separated Single Widowed

Ethnicity (please check one or indicate below)

_____ Caucasian/White

_____ Aboriginal/First Nation

_____ South Asian

_____ Hispanic

_____ African-Canadian/Black

_____ East Asian

_____ Middle Eastern

_____ Other (please identify): ___________________

School Enrolment (please circle one)

Full time Part time Not enrolled

What subject are you majoring in? ___________________

Please list the name(s) of prescribed medication(s) and/or over-the-counter medications you are currently taking:

Please check the box if you are currently taking some form of hormonal birth control. ☐

Please indicate the number of days since the first day of your last menstrual cycle: _______

Please indicate if you have any dietary restrictions (i.e. vegan, vegetarian, food allergies/intolerances):

Are you currently dieting to lose weight? Yes ☐ No ☐

Appendix V
Instructional Sets for MIST Stress Conditions

If participant is in the MIST stress + certain safety condition: "It seemed like that was hard for you. We'll just continue on with the rest of the study. I won't make you do any tasks like that again. I promise that the rest of the tasks that I'll be asking you to engage in will be easy peasy... no sweat at all!"

If participant is in the MIST stress + uncertain safety condition: "Unfortunately, your performance on this task *still* didn't meet the minimum level of performance required for this portion of your data to be used in the study. But I guess we'll continue on. We'll have to see how you manage with the rest of these tasks..."

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Appendix W
Participant Information Letter – Study Two

Dear Potential Participant:

You have signed up to participate in a research study being conducted by Laura McGeown, a Ph.D. student, under the supervision of Dr. Ron Davis in the Department of Psychology at Lakehead University. This study is interested in examining the relationship between one's heart activity, cognitive abilities, and sensory perception. This laboratory session will take approximately 120 minutes of your time.

The EEG recording will require that you wear a tight-fitting cap. Be aware that the application of the EEG cap requires a small amount of conductive gel be applied to your scalp. This gel can be easily removed from your hair. You will also be asked to place three electrodes on your chest to record your heart activity. For your privacy, we will be in the other room while you are applying these electrodes. However, there should be no need for you to remove any of your clothing to apply these electrodes. Two electrodes will be placed around your right eye, with one above and one below, to record your visual activity for the EOG recording. After a baseline recording of your cardiac activity, you will be asked to engage in a working memory task and a sensory perception task while your heart activity is recorded to examine how your heart activity may interact with your performance. Once these tasks are completed, you will be asked to fill out demographic and additional questionnaires. Your height and weight will also be measured, as these variables can affect one's heart activity. As you may be allocated to a taste condition for the sensory perception task, please notify the researcher if you have any food allergies or intolerances. The food items will not contain any nuts, but may include dairy and/or gluten.

Your participation in this study is completely voluntary. You may withdraw your consent at any time, with no penalty. All of the information provided will be kept completely confidential. Only the researcher, Laura McGeown, and research supervisor, Dr. Ron Davis, will be permitted to view your data. However, Dr. Davis is never made aware of the identities of any students who volunteer to participate in this study. The information you provide will be assigned a code that is unattached to your name, and he will only be permitted to view the data from the study once it has been anonymized. In this way, it will be ensured that your participation will not result in any biases for or against you if you are currently enrolled in any of his courses. Any identifying information will be kept confidential in any reports or publications of the results. All information will be securely stored on a password protected computer located in a double-locked research office in the Department of Psychology at Lakehead University Thunder Bay Campus for 5 years, as per University regulations.

Please note that the online survey tool used in the study, SurveyMonkey, is hosted by a server located in the USA. The US Patriot Act permits U.S. law enforcement officials, for the purpose of anti-terrorism investigation, to seek a court order that allows access to the personal records of any person without the person's knowledge. In view of this we cannot absolutely guarantee the full confidentiality and anonymity of your data. With your consent to participate in this study, you acknowledge this.

This study has the potential to benefit you from the learning experience of participating in psychological research. A risk associated with your participation in this study is that the act of completing some of the tasks and/or questionnaires may cause an emotional reaction in light of how you perceive your performance and/or the questions. You may choose not to complete any of the tasks or answer any of the questions asked without penalty or consequences. If at any point after this study you would like to speak to a mental health professional, feel free to contact the Student Health and Counselling Centre located in the Prettie Residence in person or by telephone at 807-343-8361.

If you are registered in a Psychology undergraduate course eligible for bonus points, your participation by way of attending the laboratory visit would lead to 2.5 bonus points credited to your final grade in that course. You will also receive a $10 token honorarium to thank you for your participation. Please feel free to contact Laura McGeown at lmcgeown@lakeheadu.ca or Dr. Ron Davis at ron.davis@lakeheadu.ca if you have any questions regarding your participation.

This study has been approved by the Lakehead University Research Ethics Board. If you have any questions related to the ethics of the research and would like to speak to someone outside of the research team, please contact Sue Wright at the Research Ethics Board at 807-343-8283 or research@lakeheadu.ca.

If you wish to receive a summary of this study's findings, please email Laura McGeown at lmcgeown@lakeheadu.ca and indicate the email address where the results should be sent to. The results will be sent at the conclusion of the study once all analyses have been conducted. You will not be identified directly or indirectly through this process.

Sincerely,

Laura McGeown lmcgeown@lakeheadu.ca
Dr. Ron Davis ron.davis@lakeheadu.ca (807) 343-8646

Lakehead UNIVERSITY

Appendix X
Participant Consent Form – Study Two

By providing my name and signature below, I indicate that I have read the "Participant Information Letter" and that I have had the opportunity to receive satisfactory answers from the researchers concerning any questions that I might have about my participation in the **Coming from the Heart: The Role of Heart Activity in Cognition and Perception study.** I understand and agree to the following:

1. I understand all of the information in the "Participant Information Letter";
2. I am a volunteer and can withdraw at any time from this study without penalty or consequence;
3. I may choose not to answer any question asked in the questionnaires without penalty or consequence;
4. I understand that completing some of the questionnaires and tasks may cause an emotional reaction depending on how I think about myself and how I perceive my performance;
5. All information I provide will be kept confidential;
6. My personal information will be securely stored in a double-locked research office in the Department of Psychology at Lakehead University Thunder Bay Campus for 5 years as per University regulations;
7. Dr. Ron Davis is never aware of the identities of those who volunteer to participate in this study;
8. My personal information will remain anonymous should any publications or public presentations come out of this project;
9. I may receive a summary of this research upon completion if I so request;
10. I agree to participate in this study.

____
Full Name (*please print*)

____
Date

____
Signature *(please sign)*

____
Student Number

Lakehead UNIVERSITY

Appendix Y
Participant Debriefing Email – Study Two

Dear Participant:

Thank you again for your participation in the study entitled, "Coming from the Heart: The Role of Heart Activity in Cognition and Perception." We purposefully did not explain the true purpose of the study at the time of your participation. It was explained that the purpose of the study was to examine the relationship between one's heart activity and various sensory and cognitive tasks. Although it is true that we were examining cardiac responses to these tasks, the true purpose of the study was to examine how your heart activity in response to stress may have predicted your attention towards food stimuli during the supposed "reaction time" task and your later food consumption during the supposed "taste perception" task. The "taste perception" task was not randomly selected as indicated. All participants completed this taste test task.

The deception regarding the purposes of these tasks was done for multiple reasons. Firstly, previous studies have shown that individuals may alter their eating behaviour when they know that it is under scrutiny in a laboratory situation. More generally, when the predicted response is clearly stated, it is possible that some individuals participating in a study may not act naturally and may be influenced by the experimenters and perceptions of their expectations. Therefore, to properly address the research question and ensure valid results were obtained, it was necessary to include deception about the purpose of this study.

For those in the stress condition, the "working memory" task was presented in a highly stressful manner. The arithmetic problems were timed so that the time limit would be 10% less than the average time it took to respond to the training items. The time limit also decreased if three correct answers were provided in a row. This was done to induce a high failure rate. For participants in this condition, the researcher also added additional stress in between each block of items by comparing your performance to the "average." The stress condition was further broken down into two groups. Half of those in the stress condition were informed after the first round of the task that they would not complete the task again and that the rest of the tasks would not be stressful. The other half of the stress condition was simply informed they would continue with the rest of the tasks. This was done to alter the concern that further stressful tasks may be encountered. If you were in either stress group, the researcher later told you that she pressed a wrong button after the taste test. This was done to reduce the risk that you would feel poorly about your performance, since the task had been designed to be beyond your mental capacity.

For those in the control condition, you would have simply completed a number of arithmetic problems without additional stress from the researcher or a set time limit. The second round of the task was included to account for the second round completed by those in the stressful condition to ensure an equal time commitment in the laboratory.

Please feel free to contact Laura McGeown and/or Dr. Ron Davis if you have any concerns or questions about your participation or the study in light of this disclosure, and we will be happy to answer any questions you may have. If you have any questions related to the ethics of this study or your rights as a research participant and would like to speak to someone outside of the research team, please contact Sue Wright at the Research Ethics Board at 807-343-8283 or research@lakeheadu.ca.

If you wish to receive a summary of this study's findings, please email Laura McGeown at lmcgeown@lakeheadu.ca and indicate the email address where the results should be sent to. Your participation in this study is greatly appreciated. We hope that you found your participation in this study an interesting and valuable experience.

Sincerely,

Laura McGeown lmcgeown@lakeheadu.ca
Dr. Ron Davis ron.davis@lakeheadu.ca (807) 343-8646