HEART RATE VARIABILITY AS A BIOMARKER FOR SELF-REGULATION: DOES RESISTING TEMPTATION FOR CHOCOLATE DEPLETE THE LIMITED RESOURCE?

By

Loretta Blanchette

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Abstract

Experimental evidence supports the notion that lapses in behavioural self-regulation are a function of prior depletion of the self-regulatory resource (Baumeister, 2002). Resisting desirable foods such as chocolate can subsequently lead to increased food consumption. This constitutes the behavioural rebound effect as observed by Erskine (2008) through the use of a thought suppression technique. Using a relatively new psychophysiological measure, heart rate variability (HRV), Segerstrom and Solberg Nes (2007) discovered that expenditure of self-regulatory resource through instructions to eat carrots and resist chocolate led to subsequent decrements in HRV. The purpose of the present study was to partially replicate the work of Erskine (2008) to investigate whether active attempts to resist temptation induced through interaction with chocolate causes increases in consumption of chocolate when given the opportunity to eat ad libitum. A further purpose was to determine whether HRV responds to efforts to resist temptation. Female participants (n = 83) were randomly assigned to one of three experimental groups: crave vs. resist chocolate vs. no-instruction control. Those in the craving and resistance conditions viewed 12 neutral images and 21 chocolate images and were prompted to crave or resist the images, while those in the control condition viewed neutral images with no instructions. Instructional set did not have a significant impact on chocolate consumption or cardiac function. However, an unexpected marked increase in heart rate and decrease in HRV following a chocolate taste test was observed. Potential psychological and pharmacological causes of this reactivity to chocolate are discussed.

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Heart Rate Variability as a Biomarker for Self-Regulation: Does Resisting Temptation for Chocolate Deplete the Limited Resource?

The human mind has a remarkable and unique capacity to individually alter its responses to the environment. In response to a milieu of perennial temptations and cravings that, for some, often lead to a failure to inhibit impulses, human beings have adaptively learned to regulate their behaviour (Muraven, Tice, & Baumeister, 1998). Self-regulation can be defined as a "capacity to alter or override one's responses, including thoughts, emotions, and actions" (Baumeister, 2002, p.129). This essential human attribute is critical for humans to reside together as a society. Eating disorders, binge eating, unwanted pregnancy, addictions, alcohol/drug abuse, impulse problems, procrastination, and criminal behaviour all involve some degree of a lapse of self-regulation (Baumeister & Heatherton, 1996; Ricciardelli, Williams, Finemore, 2001; Tangney, Baumeister, & Boone, 2004; Tice & Baumeister, 1997). Given that failures to inhibit impulses can have noxious repercussions, it is important to understand the biological underpinnings of this psychological construct.

Elucidating the physiological processes of self-regulation is essential to developing a reliable method to screen for lapses in self-regulation, improve self-control, and understand the functions of the self. Baumeister, Vohs, and Tice (2007) proposed that uncovering biological substrates of lapses in self-regulation is fundamental to human welfare. Understanding self-regulation and acquiring objective methods to measure it could give individuals insight as to when they are more likely to give in to their impulses.

Heart rate variability (HRV), which is a measure of interval fluctuations between heart beats, has recently been proposed to represent a biomarker for self-regulation (Segerstrom & Solberg Nes, 2007). Individuals tend to physiologically differ in their self-regulatory capacity.

High resting HRV has been associated with a number of salubrious outcomes including greater emotional regulation and an adaptive behavioural coping repertoire (Appelhans & Luccken, 2006; Fabes & Eisenberg, 1997), enhanced performance on cognitive and attention tasks (Johnsen et al., 2003), and better impulse control (Allen, Matthews, & Kenyon, 2000). In contrast, research shows that heightened cardiac reactivity and prolonged cardiac recovery to baseline measures including measures of HRV following a stressor can be detrimental to physical and psychological health (Carroll et al., 2001; Hessler & Katz, 2007; Key, Campbell, Bacon, & Gerin, 2008). Thus, changes in cardiac parameters are a key biological phenomena necessitating research into the construct of self-regulation.

Self-Regulation

Again and again people fail at changing their behaviour despite their best intentions. Losing weight, quitting smoking, decreasing drinking habits, and New Year's resolutions are classic attempts at self-regulation that often degenerate into failure. Prochaska, Diclemente, and Norcross (1992) note that 85% of smokers relapse, and 60% of individuals whose New Year's resolutions were unsuccessful will make the same promise again the next year. Baumeister and colleagues conceptualize an individual's capacity for self-regulation as a limited resource that enables people to control their impulses and desires (Baumeister & Heatherton, 1996; Baumeister, et al., 2007; Muraven & Baumeister, 2000; Muraven et al., 1998). Resource, strength, and capacity are terms that have been used interchangeably by Baumeister and colleagues. This limited resource is considered akin to the strength of a muscle that, metaphorically, can become temporarily depleted, subsequently replenished, and made stronger with practice. Once the muscle becomes depleted by acts of self-control, performance on subsequent tasks is compromised (Baumeister et al., 2007). Depletion of the self-regulatory muscle can thus be measured by examining behaviour.

Experimental evidence demonstrates that depletion of the self-regulatory resource affects subsequent performance despite an individual's best intentions. For instance, dieting demands a great deal of self-control (Kahan, Polivy, & Herman, 2003; Muraven & Baumeister, 2000). Depletion of self-regulatory resource consequently prompts many dieters to overindulge and this consequently exacerbates body dissatisfaction (Kahan et al.). Vohs and Heatherton (2000) sampled female chronic dieters ($n = 39$) to investigate if self-regulation would become depleted after suppressing emotional reactions to a poignant video segment from *Terms of Endearment* and, unbeknownst to the participants, affect subsequent consumption of ice cream. Those participants who were instructed to inhibit their emotions during the video, thereby representing an occasion for high self-regulation, subsequently ate more during a bogus ice cream taste test. In contrast, those who were permitted to emotionally react naturally to the video (low self-regulation) reported more dysphoric feelings. However, this did not render them susceptible to overindulgence, as they ate significantly less ice cream. A limitation of this study concerns the lack of a non-dieting control group. This would be essential to ensure that dietary indulgence following self-regulatory depletion is not caused by a unique factor or attribute within restrained eaters.

Most research on self-regulatory processes has narrowed in on the control component of behaviour, particularly performance on a subsequent task. For instance, Muraven, Tice, and Baumeister (1998) found that participants who were asked to suppress thoughts about a white bear subsequently gave up more quickly on a seemingly unrelated anagram solving task compared to control participants, and compared to participants who were instructed to think about the bear as much as possible. Thus, engaging in thought suppression appears to deplete the self-regulatory resource and compromise subsequent ability to control behaviour. Recent research also suggests that depletion leads individuals to act on impulses instead of deliberate intentions. Automatic attitudes or spontaneous evaluations towards chocolate candies have been discovered to elicit impulses towards eating following self-regulatory depletion (Hofmann, Rauch, & Gawronski, 2007).

A tug-of-war wages between impulses and self-control (Muraven & Baumeister, 2000). Hofmann, et al. (2007) asked participants ($n = 51$) to suppress emotions (high self-regulation) or express emotions (low self-regulation) while watching a movie clip, and subsequently partake in a bogus taste test of a product often sold in movie theatres (m&m's®), and then complete a dietary restraint scale. Automatic attitudes, which are spontaneous evaluations that predict spontaneous behaviours, were measured during an implicit association test (IAT). To measure each participant's automatic attitude toward m&m's®, pictures of m&m's® paired with positive and negative pictures or words were presented to each participant on a computer screen. These researchers expected that candy consumption would be predicted by conscious dietary restraint standards when self-regulation resources were high, whereas consumption would be predicted by preconscious automatic attitudes when self-regulatory resources were low. Indeed, when self-regulation was high, candy consumption was related to conscious dietary standards elicited by the questionnaire, and not to automatic candy attitudes; when self-regulation was low, candy consumption was related to automatic attitudes elicited by the IAT. The authors note that there is conflict between self-control, reflective tendencies, and impulsive tendencies. Reflective tendencies based on conscious personal standards have been proposed to exact more of the self-regulatory resource whereas impulses use up less. Therefore, an individual may act on impulses when self-regulatory resources are depleted. It may have been beneficial for these researchers to assess conscious personal restraint standards before candy consumption as responses may have been altered due to the depletion exercise. Despite this limitation, this study provides evidence for a tug-of-war between controlled and deliberate actions based on personal standards and impulsive actions based upon automatic attitudes.

Stronger over weaker impulses have been considered more difficult to control (Baumeister & Heatherton, 1996; Baumeister et al., 1998; Heatherton & Baumeister, 1996). Thoughts of chocolate can elicit strong cravings and desires (Van Gucht et al., 2008). Baumeister et al. sampled 67 undergraduates to investigate if eating carrots and resisting the strong temptation for warm chocolate cookies would subsequently cause participants to surrender more quickly in their attempts to solve a frustrating puzzle. The researchers surreptitiously watched each participant complete the task and noted the amount of time that each participant persisted on the puzzle. Indeed, participants forced to eat the carrots only persisted at the task for 8.4 min as compared to those permitted to indulge in the warm chocolate cookies, who persisted for 18.9 min. Therefore, resisting the impulse to indulge in warm chocolate cookies is one act that depletes the self-regulatory resource.

One proposed theory for depletion of the limited resource is that of conservation. Baumeister (2002) suggests that depletion seems to motivate an individual to garner the scarce resource. For instance, people engage in proactive coping by preparing for future losses through conserving their resources (Aspinwall & Taylor, 1997). Moreover, Muraven, Shmueli, and Burkley (2006) discovered that individuals will conserve the limited resource when anticipating the need for self-control in the near future. Participants in their study were depleted by thought suppression and some were told that they would be demonstrating emotional awareness of a stand-up comedian clip later on in the experiment. These participants subsequently pulled their hand out of ice cold water more quickly (59.1 s) compared to participants who did not expect to be depleted again through the emotional awareness task (101.5 s). The findings of conservation are intriguing and appear to be adaptive. Perhaps, as Muraven et al. note, anticipating future stressors can lead individuals to a lapse in self-regulation now.

How do individuals replenish the depleted resource? Rest and sleep have been discovered to assist in the restoration of self-control (Baumeister, 2002). Tice, Baumeister, Shmueli, and Muraven (2007) observed that, following a depletion task, a positive mood state also aided participants in persisting longer at a hand drawing task compared to participants induced into a neutral mood state. Perhaps a positive mood state does in fact replenish the limited resource. Alternatively, as the authors suggest, it may allow the individual to expend more of their scarce resource.

At a physiological level glucose which is an essential fuel for the brain has been associated with self-regulation. Masicampo and Baumeister (2008) indicated that glucose has been shown to drop significantly during acts of self-regulation, and that low glucose after a depletion task led to poorer self-regulation on a subsequent task. Moreover, replenishing glucose by consuming a glucose-rich drink decreased lapses of self-control and increased performance. Therefore, the self-regulatory resource is biologically expensive. So far, most research on the self-regulatory construct has narrowed in on behaviour control. The physiological underpinnings of self-regulatory strength are currently less apparent.

Understanding both the behavioural and biological components of self-regulation is important as self-control failure can result in personal and social problems. Acts of self-control, such as resisting temptation, deplete the limited resource which can lead to compromised persistence at subsequent tasks (Muraven et al., 1998). Heatherton and Baumeister (1996) propose that identifying measures of individual differences in self-regulation is critical to bolster the self-regulatory theory. Examination of individual differences of the self-regulatory resource is important to augment the literature and pragmatically aid clinicians to understand what demands on the limited resource are currently central to their clients' lives. Most research to date has focused on identifying behavioural measures of self-regulation. Efforts to find biological underpinnings would advance the literature. Measures of heart rate variability offer just that opportunity.

Heart Rate Variability

An objective biological measure of the self-regulatory resource is heart rate variability (HRV) (Segerstrom & Solberg Nes, 2007). In the late 1960's, psychophysiologists began to measure the beat-to-beat changes in heart rate and titled this HRV (Appelhans & Luecken 2006; Porges, 2007). At this time, psychophysiologists used the polygraph to investigate the connection between HRV and psychological processes. Originally, HRV was considered error variance engendered by environment or experimental errors. However, this hypothesis does not coincide with current knowledge of the interaction between the heart and the central nervous system (CNS) and peripheral nervous system (Porges). More recently, HRV has emerged as a marker of individual differences in regulating behaviour especially in the domain of emotional regulation (Appelhans & Luecken).

The peripheral nervous system includes the autonomic nervous system which is divided into the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS) which act antagonistically to impact heart rate. HRV is influenced by environmental cues such as danger and by physiological factors, which elicit continuous oscillations throughout the day between sympathetic and parasympathetic control. Activation of the SNS has an excitatory effect and increases heart rate. In contrast, activation of the PNS has an inhibitory effect which is activated at rest and increases the intervals between heart beats (Appelhans & Luecken, 2006). A fast heart rate corresponds to short intervals between beats in the range 0.15-0.50 Hz and a slower heart rate to longer intervals (<0.04Hz) (Rottenberg, Clift, Bolden, & Salomon, 2007). The interplay between the SNS and PNS thus influences HRV. HRV in turn resembles the moment-to-moment output of the central autonomic network (CAN) and recent evidence suggests that it can serve as a biomarker of an individual's capacity to regulate behaviours (Appelhans & Luecken).

Empirical research has focused on cardiac vagal tone as a correlate of regulated emotional response (Appelhans & Luecken, 2006; Thayer & Brosschot, 2005). The tenth cranial nerve, the vagus nerve, and the PNS collaborate to bring the heart beat to a tonic state. Withdrawal of vagal nerve activity enables heart rate to increase in the face of critical circumstances such as environmental stressors. Vagal tone can be measured via examination of HRV that is synchronized with respiration. This is called respiratory sinus arrhythmia (RSA) (O'Connor, Allen, & Kaszniak, 2002). Greater vagal tone corresponds to increased HRV.

Greater HRV seems to reflect a greater ability to regulate affect (Appelhans & Luecken, 2006; Friedman, 2007; Thayer & Brosschot, 2005). It has also been associated with salubrious outcomes including better impulse control, enhanced cognitive functions, emotional regulation, and coping (Thayer & Brosschot). Moreover, meditation has been shown to increase vagal tone (Phongsuphap, Pongsupap, Chandanamattha, & Lursinsap, 2008). In contrast, low HRV reflects inflexibility in response to environmental cues and has been associated with maladaptive behaviours and adverse health outcomes such as negative emotions when under stress, anxiety, depression, diabetes mellitus, and cardiovascular disease (Appelhans & Luccken; Rottenberg et al., 2007; Thayer & Lane, 2000; Thayer & Lane, 2007). For instance, O'Connor, Allen, and Kaszniak (2002) examined HRV and the difference between depression and depressed feelings that accompany the loss of a loved one. Possibly due to the small sample size, no significant group differences in HRV were found. However, individuals experiencing higher levels of depression within the bereaved group showed lower HRV. This suggests that HRV may be connected to mental health with greater HRV being associated with more positive outcomes.

Autonomic flexibility as manifested through higher HRV has also been associated with attentional regulation which is critical for cognitive functions (Thayer & Brosschot, 2005). Johnsen et al. (2003) discovered that higher HRV is related to quicker reaction times on a Stroop task. The HRV of dental phobics (n = 20) was measured using an ambulatory monitoring system while participants were exposed to images of dental treatment and a subsequent attentional Stroop task. The Stroop task consisted of four conditions: colour-congruent, colour incongruent, dental threat and neutral words. Threatening words and incongruent images arrested the attention of participants and both elicited longer reaction times. However, compared to those with lower resting HRV, participants with higher resting HRV displayed faster reaction times. HRV also abated for all participants after exposure to images and the Stroop task. Although Johnsen et al. did not examine behavioural manifestations of self-regulation in this study, it is interesting to speculate that exposure to threatening dental images may have depleted self-regulatory strength, thereby leading to longer reaction times.

HRV has been directly investigated as an index of self-regulatory strength and effort. Segerstom and Solberg Nes (2007) manipulated self-regulatory strength by presenting participants (n = 168) with a platter that had chocolate chip cookies, chocolates, and carrots and asking some participants to resist (high self-regulation) or indulge (low self-regulation) in the cookies. Persistence at an anagram task was measured subsequent to the manipulation. HRV dropped during the manipulation tasks. During high self-regulatory effort (eat carrots and resist cookies), HRV dropped 8% and in the low effort (eating cookies and resist carrots) condition HRV dropped 25%. Moreover, participants who persisted longer on the anagram task had higher resting HRV at baseline. A limitation concerning the external validity of this study is that participants were not given a choice as to whether or not they would like to eat cookies or carrots. In natural settings, individuals are faced with making choices about which foods to consume and their everyday choice may be an indicator of their self-regulatory capacity. Perhaps if these researchers provided participants with the opportunity to exert free will over choice of cookies versus carrots, HRV and persistence would have been modified accordingly. The opportunity to exert free will may provide an avenue to examine individual differences in self-regulatory capacity.

Research with addictive substances such as alcohol has shown that some individuals have a unique capacity to resist temptation. Igjaldsson, Laberg, and Thayer (2003) examined HRV in alcoholic participants and controls. Participants ($n = 94$) completed a series of questionnaires relating to mood, impulsivity, alcohol dependence, and craving. Subsequently, participants watched 26 slides of alcoholic and non-alcoholic beverages and were asked to recall experiences where alcohol was tempting. Alcoholic participants had lower resting HRV compared to controls. Moreover, those alcoholic participants who reported that they were able to resist temptation to alcohol displayed increases in HRV when exposed to images of alcoholic beverages. Alcoholic participants who reported that they could not resist temptation did not display an increase in HRV. Thus, these findings allude to the notion that individuals whose

HRV increases after exposure to tempting images seem to possess a unique capacity to resist temptation. Perhaps one root to adverse mental health lies in an impaired PNS response to an environmental challenge.

Cardiac Reactivity and Recovery

Physiological changes that occur within a normal range in stressful situations are part of a natural and adaptive response mechanism. However, in some instances, physiological changes are exaggerated and this response is believed to also adversely affect psychological and physical health (Key et al., 2008; Lovallo & Gerin, 2003). Cardiac reactivity, or the changes that occur in the heart when faced with a stressor, is one measure to examine such exaggerated responses (Obrist, Light, Sherman, & Strogatz, 1987). Lovallo and Gerin's cardiac reactivity hypothesis proposes that individuals are at an increased risk of cardiovascular disease when they possess an exaggerated physical or psychological stress response. Indeed, heightened cardiac reactivity observed through increased heart rate leads to hypertension (Carroll et al., 2001). Therefore, the psychosomatic impact of stress can have adverse ramifications for the health of individuals.

The cardiac reactivity hypothesis is an important paradigm for examining the implications of psychosomatic stress. However, there appears to be a significant flaw with this hypothesis. The cardiac reactivity hypothesis focuses on acute responses, often occurring during laboratory stress rather than in the natural environment, and ignores the subsequent recovery from this acute response (Linden, Earle, Gerin, & Christenfeld, 1997; Phillips & Hughes, in press). Therefore, cardiac recovery is delineated as the period of time in which physiological functioning returns to baseline (Haynes, Gannon, Orimoto, O'Brien, & Brandt, 1991; Key, et al., 2008; Linden et al.). The recovery period highlights the time period in which cardiac reactivity persists after the stressor has ended (Linden et al.). This time period is important to investigate as prolonged stress that impacts both reactive elevations and prolonged recovery periods may be detrimental (Key et al.). In the late 1990's two-thirds of researchers did not report cardiovascular recovery for reasons such as recovery protocols pose greater measurement problems than reactivity protocols (Linden, et al.). However, given the importance of both of these cardiac parameters, most recent research includes both indices. Therefore, it is important to consider both cardiac reactivity and recovery following a laboratory stressor when examining the repercussions of an environmental challenge.

Pronounced cardiac reactivity and prolonged recovery have been discovered in hostile individuals (Davis et al., 2000). Vella and Friedman (2009) investigated the relationship between hostility and anger inhibition in predicting cardiovascular reactivity and recovery from an arithmetic stress test among healthy male participants. Participants in the experimental condition were exposed to verbal harassment through tape-recorded statements while performing the mental arithmetic task (i.e., "This can't be the best you can do. You're not trying hard enough") (p. 255). Participants who suppressed hostile anger (anger inhibitors) showed significantly higher diastolic blood pressure (DBP) reactivity to the mental arithmetic task. In contrast, low anger inhibitors displayed greater systolic blood pressure (SBP) recovery. There appears to be individual differences such as anger inhibition in cardiac reactivity and recovery.

Trait and state influences on cardiac reactivity and recovery have also been investigated. Friedberg, Suchday, and Shelov (2007) sampled 99 participants and discovered that higher levels of trait forgiveness are predictive of lower DBP at baseline and faster DBP recovery. These researchers suggest that trait forgiveness may aid in cardiac recovery from stress. Key et al. (2008) investigated the influence of trait and state rumination on cardiac recovery, including HRV recovery measures, subsequent to an emotional stressor. This study was composed of a baseline period, an emotional recall stress task wherein participants had 2 min to prepare a 5 min speech about a recent stressful negative life event that they found difficult to stop thinking about, and a 15 min recovery period. Participants completed a thought report at 5 and 10 min subsequent to the termination of the emotional recall task to determine whether the participant was ruminating. Results indicate that low trait ruminators that were ruminating 10 min after the stressor had less high-frequency HRV recovery and lower DBP compared to low trait ruminators who were not ruminating for the 10 min. Key et al. note that trait rumination may lead to prolonged cardiac activation subsequent to a stressor which may consequently play a role in the association between hypertension and stress.

Negative affect including depression, neuroticism, and/or anxiety have also been shown to be associated with increased cardiac reactivity and poor recovery to baseline (Chida & Hamer, 2008; Key, Ross, Bacon, Lavoie, & Campbell, 2009; Pieper & Brosschot, 2005). For instance, Key et al. (2009) discovered that depressed mood is associated with increased heart rate (HR) reactivity and less DBP recovery among healthy undergraduate women. However, the influences of positive affect on cardiac parameters have been less thoroughly examined. One study that explicitly examined the influence of positive affect and cardiac recovery was conducted by Papousek et al. (2010). These researchers hypothesized that trait positive affect may protect against prolonged recovery from a stress task. Participants (n = 65) underwent a 3 min baseline period wherein participants were instructed to sit still and look at a green dot on the screen in front of them, a 3 min anticipation period, a 3 min challenge task, and 5 min recovery period. In the anticipation period, participants were told that they would listen to a recording and subsequently deliver a performance (i.e., answer a question they should be able answer in order to pass their statistics exam). Their answer would be videotaped and evaluated by their statistics professor. In the challenge period participants read aloud a question, which was not easy for them, and answered the question. Results revealed that higher trait positive affect is associated with greater cardiac recovery independent of negative affect. However, a positive mood while anticipating a stressor was related to prolonged recovery. Noteworthy is the finding that the relationship between trait positive affect and recovery could be explained by the sympathetically dominated measures of HRV, namely the ratio of low to high frequency (LF/HF) and low frequency (LF). However, HR and the parasympathically dominated measure of high frequency (HF), did not account for this relationship. Papousek et al. suggest that this may be because HR and HF returned to baseline during the recovery period and the recovery of LF/HF and LF was less complete. This suggests a more rapid recovery of the HR and HF than LF and LF/HF. Taken together, both negative and positive affect appear to affect cardiac reactivity and recovery.

A wealth of research has focused on the role of emotional factors in physiological responses to acute stress (Friedberg et al., 2007; Key et al., 2008; Papousek et al., 2010; Vella & Friedman, 2009). Recent research, although limited, is also beginning to consider the relationship between cardiac reactivity, recovery, and self-regulation. Hessler and Katz (2007) examined children's (n = 72) emotion regulation in response to a peer provocation situation. Each participant engaged in a mock computer game contest in which the participants' keystrokes were purposefully delayed causing them to lose the game. A child actor was trained to make a standard set of bragging and teasing comments. The participants reported their emotion dysregulation on a rating dial while watching the peer provocation video of himself or herself. Results revealed that children with greater self-reported emotion dysregulation displayed greater HR reactivity in response to the provoking peer comments. However, no differences in HR recovery were discovered. A limitation of this study was that these researchers did not include a measure of children's activity level during the physiological measurement. Hence, activity level could have interfered with cardiac responses (e.g., Hubbard et al., 2004). The overall findings suggest that emotional factors including emotion regulation are related to cardiac reactivity.

Preliminary research has also examined the effect of impulsivity on cardiac reactivity in response to smoking cues. Doran, McChargue, and Spring (2008) asked regular smokers (n = 75) to complete the Barratt Impulsiveness Scale and then smoke one of their own cigarettes. Next, all participants filled out baseline craving and smoking behaviour questionnaires for 30 min. In the neutral cue condition, participants were then asked to hold a roll of tape while those in the cigarette cue condition were asked to light a cigarette without touching it to their mouth for 10 min. Results revealed that more impulsive smokers displayed an increase in mean arterial pressure in response to smoking cues. However, impulsive smokers did not report stronger cravings or display increased HR reactivity. Doran et al. suggest that impulsive smokers may not reliably report craving because the majority of negative affective processing occurs outside of awareness. Therefore, impulsive smokers may be less aware of cravings for cigarettes. One limitation in this study is that the researchers did not examine cardiac recovery which may have shed some light on the relationship between physiological measures and cue reactivity. Examination of cardiac measures and cravings is intriguing and warrants further study.

Craving and Resistance

Food cravings are normative among the general population and not always pathological (Kemps, Tiggemann, Grigg, 2008; Lafay et al, 2001). Food cravings can be considered "a motivational state whereby an individual feels compelled to seek and ingest a particular food" (Tiggemann & Kemps, 2005, p.305). They have been associated with adverse behaviours including binge eating and obesity (Gendall Joyce, Sulivan, Bulik, 1998; Polivy, Coleman, &

Herman, 2005), guilt and depression (Fletcher, Pine, Woodbridge, & Nash, 2007). Evidence indicates that men report food cravings less often than women (Lafay et al., 2001). Weingarten & Elston (1990) discovered that 68% of men and 97% of women have experienced cravings. Yet, compared to men, women report less positive affect subsequent to indulgence (Weingarten & Elston). Sweet foods with high caloric content are the most commonly craved food. For instance, chocolate craving is highly prevalent in North America and chocolate is one of the most intensely craved substances as it is known for being highly palatable, for its pleasing aroma and smooth texture (Lafay et al.; Tiggemann & Kemps).

The elaborated intrusion (EI) theory of desire (Kavanagh, Andrade, & May, 2005), a recent cognitive model of cravings, suggests that mental imagery is essential to the craving experience (Kemps & Tiggemann, 2007). According to EI theory, cravings are elicited by intrusive thoughts about a desirable substance, become desirable through this process, and are subsequently stored in limited working memory (Kavanagh et al.). Tiggemann and Kemps (2005) sampled 130 undergraduate students to investigate which sensory modality contributed the most to craving. Vivid mental imagery was significantly associated with craving. Moreover, the sensory modalities that were highly related to craving were visual (39.7%), gustatory (30.6%), and olfactory (15.8%), respectively. Thus, desirable substances are more often craved through visual modalities.

Thought suppression is a technique that is often utilized to inhibit food cravings (Tiggemann & Kemps, 2005). The intended purpose of thought suppression is to alter behaviours (Erskine, 2008). For instance, an individual that is on a diet may suppress thoughts of chocolate as a means of inhibiting consumption of chocolate. However, resisting thoughts of cravings has been considered not only to be futile, but it also has paradoxical effects. Several researchers have observed the rebound effect whereby suppressing thoughts inevitably leads one to deliberate more frequently about the suppressed idea (Johnston, Bulik, & Anstiss, 1999; Wegner, Schneider, Carter, & White, 1987). This "rebound effect" also has been observed in the context of food intake, particularly among individuals with attitudinal conflicts about food intake such as restrained eaters, more commonly referred to as dieters.

Empirical evidence suggests that restrained eaters experience more cravings and are more likely to eat craved foods compared to unrestrained eaters (Burton, Smit, & Lightowler, 2007). For instance, Polivy, Coleman, and Herman (2005) randomly assigned restrained and unrestrained female undergraduates to one of three groups. One third of participants were asked to refrain from eating of chocolate, one third was asked to refrain from consuming vanilla, and the last third were not deprived. Each participant attended a laboratory session food deprived for 3 hr to work on a short anagram task and to participate in a bogus taste test. Participants were ostensibly told that the anagram task was being tested for research to investigate how long the task remained difficult, fun, or absorbing. Participants were also instructed to ring a bell after they decided they were finished with the anagram task and when they were ready to start tasting the chocolate. Polivy et al. discovered that chocolate-deprived restrained eaters consumed significantly more chocolate ($M = 208.4$ g) compared to unrestrained eaters ($M = 93.5$ g). Furthermore, these researchers found that restrained eaters were more eager to consume chocolate as they gave up on an anagram task more quickly ($M = 303$ s) compared to unrestrained eaters ($M = 499.9$ s). Polivy et al. attribute their findings to the behavioural rebound effect where restricting food increases its desirability and paradoxically leads to subsequent over-indulgence. However, another compatible and plausible hypothesis is that depriving participants of chocolate depletes their self-regulatory strength which, in turn, has an impact on how much chocolate they eventually consume. In fact, when examining their findings more closely, both restrained and unrestrained eaters who were not deprived subsequently persisted at the anagram tasks longer (*M* = 724.8 s; *M* = 659.1 s, respectively) compared to chocolate deprived participants (*M* = 303.0 s; *M* = 499.9 s, respectively). Therefore, it is plausible to consider that behavioural rebound may be a function of prior self-regulatory depletion, the subject of which becomes the focus of the present study.

It is evident that behavioural control and thought control impact one another (Wegner et al., 1987; Wenzlaff & Wegner, 1998). Avoiding thoughts about a desired food may lead to excess. Erskine (2008) posited that thought suppression would lead to increased chocolate consumption compared to instructions to engage in thought expression and/or no-instruction control. Participants (*n* = 134) who were not on a diet were ostensibly led to believe that the study was examining how thoughts impact taste preference. Participants were asked to either suppress thoughts of chocolate or to think about chocolate including its smell, taste, and texture for 5 min. Subsequently, a bowl with 20 Cadbury® shots and a bowl with 20 Galaxy® minstrels were presented to participants who were asked to try as many as they would like but at least one from each bowl. Males and females in the suppression condition consumed significantly more chocolates (*M* = 8.50 and *M* = 8.48, respectively) than controls (*M* = 5.86 and *M* = 5.00, respectively) and females (*M* = 5.75) in the expression condition. These results suggest a clear behavioural rebound to thought suppression. Interestingly, males in the expression condition consumed the most chocolate (*M* = 12.30). The reasoning behind this finding remains unclear. Perhaps women are more likely to be interested in restricting chocolate consumption due to Western societal body image ideal expectations. A limitation of this study is that only non-dieters were sampled. It may have been beneficial to include dieters in the sample as they would likely have consumed even more chocolate than non-dieters because they are actively and daily attempting to limit thoughts of fattening foods (Polivy et al., 2005).

The Present Study

Evidence suggests that individuals have a limited self-regulatory resource that impacts the control of impulses (Baumeister & Heatherton, 1996; Baumeister et al., 2007; Muraven & Baumeister, 2000). Thought suppression seems to decrease impulse control leading to paradoxical behaviours, particularly with chocolate indulgence (Polivy et al., 2005; Erskine, 2008). Empirical evidence suggests that HRV is emerging as an objective, physiological measure of self-regulatory capacity (Segerstrom & Solberg Nes, 2007). To our knowledge, no published study has examined HRV after depletion of self-regulatory resource via craving and resistance inductions among females.

The present study represents an attempt to partially replicate and extend the work of Erskine (2008); specifically, to investigate whether active attempts to resist the temptation induced through seeing and handling chocolate causes increases in subsequent consumption of chocolate when given the opportunity to eat ad libitum. This would constitute the behavioural rebound effect as observed by Erskine through the use of his thought suppression technique.

The present study also attempted to extend the work of Erskine to include the examination of HRV as a potential biomarker for self-regulatory resource and its depletion. Segerstrom and Solberg Nes (2007) found that expenditure of self-regulatory resource through instructions to eat carrots and resist chocolate led to smaller subsequent decrements in HRV among participants relative to those instructed to eat chocolate and resist carrots. Drawing upon this observation, the question arises as to whether the rebound effect observed in Erskine's chocolate-resisting individuals is preceded by initially smaller decrements in HRV that eventually give way to collapse; that is, larger decrements. Thus, two predictions were offered in the present study. Compared to a group of individuals instructed to crave chocolate stimuli, and to a group of individuals in a no-instruction control, those instructed to resist chocolate would (a) consume more chocolate ad libitum during a subsequent bogus taste test, and (b) evidence a greater reduction in their HRV immediately beforehand.

The present study also sought to explore cardiac reactivity and recovery within the experimental paradigm employed. Linden et al. (1997) highlight that it is essential for researcher's to report both cardiac reactivity scores and recovery scores to elucidate the underlying physiological mechanisms in response to a stressor; in the present case, to the resistance and craving inductions and subsequent chocolate consumption. A specific interest concerned the individual differences in attitudes and behaviours related to dieting and body image for their potential to predict the magnitude of cardiac reactivity and recovery observed among participants over the phases of the study. Given the exploratory nature of this objective, no specific predictions were made.

Method

Study Design

This experiment randomly assigned participants to one of three conditions that differed in instructional set: crave vs. resist chocolate vs. no-instruction control. The primary dependent variables were the physiological measures of HR and HRV assessed at multiple times throughout the experiment, and the behavioural measure of chocolate consumption. Both were considered to be indices of self-regulatory capacity. Psychometric measures of dieting, body image and sentiments about chocolate were also examined for their statistical association with the primary dependent variables, cardiac reactivity and cardiac recovery.

Participants

Eighty-five students at Lakehead University were recruited. Participants were eligible to participate if they were (a) female, (b) had no allergies to chocolate or peanut products, and (c) were not taking medications for depression, anxiety, insomnia, asthma or high blood pressure. Only women were recruited because some evidence shows that men tend to eat more after craving chocolate compared to women, and cravings tend to be more prevalent in women than men (Erskine, 2008; Weingarten et al., 1990). Participants also were not permitted to be taking certain medications that are known to influence HRV (Papousek et al., 2010).

A mass E-mail was sent out to female students in which interested participants responded (see Appendix A). A copy of the information letter, contact sheet, and consent form were provided upon arrival in the laboratory (see Appendix B). An individual laboratory time of 1 hr was scheduled for each participant. All participants were awarded one bonus point towards their Introductory Psychology final grade for participation in this study which was approved by the Lakehead University Research Ethics Board.

Materials

Orientation to Chocolate Questionnaire (OCQ; Cartwright et al., 2007; Cartwright & Stritcke, 2008; Appendix D). The OCQ assesses three factors of chocolate cravings including approach, avoidance, and guilt towards chocolate (Cartwright et al.). The OCQ craving factors differentially predict quantity and frequency of chocolate consumption and disordered eating (Cartwright & Stritzke). The OCQ includes 15 items and asks participants to rate their attitudes towards chocolate in the last month. Items range from 1 (*not at all)* to 9 (*very strongly*). The OCQ displays good concurrent and discriminant validity (Cartwright & Stritzke). No published study has examined internal consistency or test-retest reliability.

Eating Disorder Examination-Questionnaire (EDE-Q; Fairburn & Belgin, 1994; Appendix E) The EDE-Q is a self-report questionnaire that focuses on retrospective recall of eating attitudes and behaviours (Grilo, Masheb, & Wilson, 2001). Using a 7-point scale ranging progressively from 0 (*no days*) to 6 *(every day)* , this 36-item questionnaire contains four subscales; Dietary Restraint, Eating Concern, Weight Concern, and Shape Concern (Grilo et al.). Participants rate their attitudes and behaviours over the past 28 days. The EDE-Q has displayed good criterion and discriminant validity for the subscales and global scale (Mond et al., 2004). Test-retest reliability coefficients range from .81 to .94 and Cronbach's alphas ranging from .78 to .93 (Carter, Stewart, & Fairburn, 2001; Luce & Crowther, 1999).

Dutch Restrained Eating Scale (DRES; van Strien, Frijters, van Staveren, Defares, & Deurenberg, 1986; Appendix F) The DRES is a 10-item measure that utilizes a 5-point scale with 1 (*never*) to 5 (*always*) to assess dieting behaviour. Higher scores are indicative of heightened dieting behaviour. Excellent test-retest reliability of $r = .92$ (2-week period) and internal consistency of $\alpha = .95$ have been reported (Allison, Kalinsky, & Gorman, 1992).

Cardiac recording. Data was collected using a Polar WearLink® 31 Transmitter (Polar RS800) chest strap transmitter and heart rate wrist monitor which measures heart rate ranges between 15-240 beats per minute (www.Polarusa.com). Recordings were processed through specialized HRV analysis software (Kubios HRV; http://kubio.uku.fi). Kubios HRV analysis software was developed by the Biosignal Analysis and Medical Imaging Group (BSAMIG) at the University of Kuopio, Finland (Tarvainen & Niskanen, 2008). HRV measures the beat-to-beat changes between consecutive heart beats rather than heart rate. The sinoatrial (SA) node, which controls the rhythm of the heart, is modulated by both the SNS and PNS. Variations in heart rate are the result of continuous modulation of the SNS and PNS. HRV analysis examines the sinus rhythm which is modulated by the SNS and PNS. To derive the HRV time series, QRS complexes (ventricular depolarizations) were estimated and the inter-beat intervals (RR intervals) were acquired as differences between R-wave occurrence times. A power spectrum density (PSD) estimate was calculated for the RR interval series. The PSD estimate is carried out by a fast-fourier transformation (FFT), which is a mathematical algorithm that transforms a function from a time domain to frequency domain, to give the HRV power spectrum (Tarvainen & Niskanen). The frequency domain measures were used because more experience and theoretical knowledge exist on the interpretation of short-term frequency domain recordings compared to time domain recordings (Task Force, 1996).The analysis software produced estimates of high frequency (HF) band powers in the HRV power spectrum, which are thought to be of parasympathetic origin, and low frequency (LF) band powers, which are expected to be mainly of sympathetic origin (Tarvainen & Niskanen). The ratio between low to high frequency (LF/HF) band powers in the power spectrum were also produced by the analysis software. Higher LF/HF ratios are interpreted as lower HRV.

To prevent artifacts in the physiological signals such as ectopic beats and arrhythmic events from interfering with analysis, the event series were detrended automatically by the program. The event series were also checked manually, in the event that artifactual data were missed by the correction algorithm (Tarvainen & Niskanen).

The Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996) recommends that HRV parameters be calculated from short-term recording intervals of 2 to 5 min. Therefore, at each of the five phases of the experiment, the cardiac parameters were analyzed in 4-min segments. Each 4-min segment pertained to the latter 4-min of each phase.

Nunan et al. (2008) report excellent to good validity of cardiac recordings using the Polar S810 heart rate monitor and accompanying software. In addition, the Polar S810 did not add any technical error or noise when compared to criterion measures of the more conventional gold standard two-lead ECG recording. Validity correlation coefficients (*n* = 33) for log-transformed measures ranged from 0.99 for *SD* of normal-to-normal intervals to 0.87 for the ratio of low-to high- frequency spectral power (i.e., LF/HF). To examine reliability, Nunan et al. (2007) sampled 19 males and 14 females at rest for 10 min at three time points and recorded RR intervals. The Polar S810 displayed similarly acceptable to good reliability of short-term HRV as the two-lead ECG.

Chocolate stimuli. Chocolate was chosen for this study as it is one of the most intensely craved substances (Fletcher et al., 2007; Van Gucht et al., 2008). Participants viewed 30 full colour images of chocolate along with the written word *"chocolate"* (see Appendix G). Empirical evidence suggests that cravings can be induced through imagery (Kemps & Tiggemann, 2007). Moreover, presenting the word *"chocolate"* has also been shown to elicit cravings (Pelchat, Johnson, Chan, Valdez, & Ragland, 2004). Following the procedures of Berube-Hayward (2008), chocolate images and the word chocolate were utilized to induce temptations for chocolate among participants. The participants viewed each image for 7 s on a 70-inch DLP television positioned approximately 2 m in front of them. Participants in the control condition received no instruction while viewing neutral images of castles only.

To examine the behavioural component of lapses in self-regulation, three flavours of chocolate candies (Smarties®, m&m's®, and Reese's Pieces®) were offered to each participant to examine consumption. Following the methodology of Bola (2007), each flavour was placed in a separate bowl with 150 candies in each bowl (450 total per participant). Before being presented to the participant, each bowl was weighed using a digital scale.

Procedure

Prior to the experimental session, participants were told that the purpose of the study was to measure cardiac responses related to food preferences such as chocolate. Participants were asked to abstain from caffeinated beverages, tobacco, and food for at least 1 hour prior to coming into the lab (see Appendix A).

Individual laboratory sessions included five phases of the experiment over the course of 1 hr (see Figure 1). To experimentally manipulate self-regulatory effort, participants were randomized to one of three instructional sets: crave versus resist chocolate versus no-instruction control. Participants were asked to read the information sheet and sign the consent form (see Appendix B). Participants were asked to strap the Polar RS800 chest strap transmitter and heart rate wrist monitor to their body.

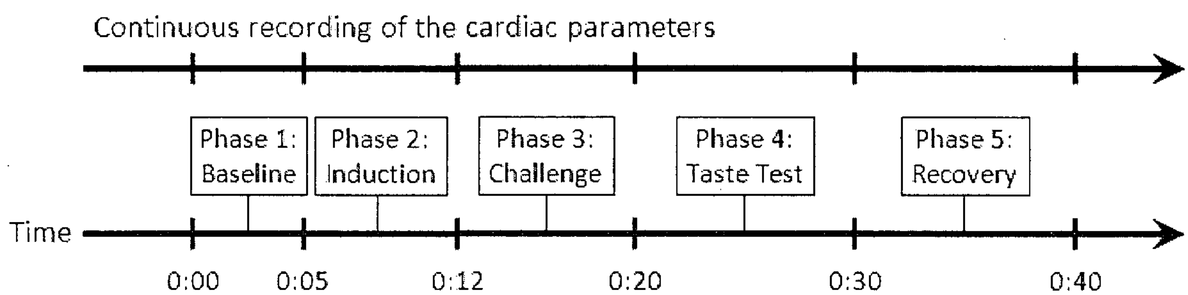

Figure 1. Timeline in minutes of laboratory experimental procedure.

Following the methodology of Berube-Hayward (2009), participants were asked to sit in a dimly lit room and their HRV was continuously recorded for the duration of the experiment. Phase 1 consisted of all participants viewing 5 min of 12 neutral pictures (e.g., blender, battery, etc.) on the TV. During phase 2, participants in the craving and resisting conditions were asked to view 21 pictures of foods containing chocolate for 7 min and were simultaneously and repeatedly prompted with written words on the TV screen to induce craving (e.g., *"Don't think about anything except chocolate")* or resistance (e.g., *"Resist thinking about chocolate"*). Participants in the control condition continued to view neutral pictures of castles with no instructions for the next comparable 7-min period. At phase 3, craving and resisting participants were presented with a plate containing a small (18g, 100 calories) and a large (100g, 535 calories) Cadbury® dairy milk chocolate bar. Participants were instructed to pick one of the two chocolate bars and interact with it by breaking it in half, smelling, and visually examining the chocolate for the next 8 min. Participants were instructed not to eat the chocolate bar. No-instruction control participants were instructed to interact with a calendar containing pictures of castles and choose the castle that they liked best for a comparable period of time.

During phase 4 all participants were presented with 3 bowls of candy covered chocolate (Smarties®, m&m's®, and Reese's Pieces®) and a bottle of water and were told this phase of the experiment would examine cardiac responses to a chocolate taste test. Following the procedures of Bola (2007), participants were told that they would sample three flavours of candy, fill out taste rating forms (Appendix I), and were told that the experimenter would leave the room during the taste test. The candies were weighed and counted before being presented to each participant. The candies were presented in the same order for each participant beginning with Smarties®, then m&m's®, and lastly Reese's Pieces®. The bowls were presented as "A", "B", and "C". Participants were given verbal instructions for the "taste test" by the experimenter who then left the participant alone for 10 min. Participants were instructed to drink water to cleanse their palate and then sample just enough of candy "A" to complete the taste preference ratings. Participants were then instructed to take another sip of water and move on to candy "B". Once again participants were asked to eat just as much of the candy as necessary to complete the ratings and were told that once they moved on to candy "B" they could not change their ratings of candy "A". After sampling candy "B", participants were asked to move onto candy "C" following the same protocol. Participants were also informed that following their taste test and ratings, they would be permitted to eat as many candies as they like as there were "plenty" left.

During the final phase 5, all participants were left alone for 10 min to complete the psychometrics. Participants filled out a demographics questionnaire (see Appendix C) and then completed the OCQ, EDE-Q, and DRES. Participants were then asked to remove the heart rate transmitter and thanked for their participation. After all the data was collected, participants were E-mailed a full debriefing (see Appendix K) in which the true purpose of the taste test was revealed. Participants were given the opportunity to withdraw their data at that time; no one did. The true purpose of the study was revealed after all data was collected in order to ensure that the participants' eating behaviours were not influenced during the taste test.

Data Analysis

The dependent variable of chocolate consumption (weight consumed in g over 10 min) was subjected to a one-between subjects analysis of variance (ANOVA) as a function of experimental condition. The between-subjects condition represents the independent grouping variable with three levels; craving versus resisting versus no-instruction control. Data was also analyzed using one-between multivariate analysis of variance (MANOVA) for phases 2 and 3 to determine the effect of instruction on the four cardiac parameters. In addition, a mixed one-between (instruction) and one-within (phase) MANOVA was conducted with dependent measures including the four cardiac parameters. Hierarchical multiple regression analyses were performed to investigate if any of the psychometric variables predicted cardiac reactivity and/or recovery.

Results

Preparation of Data

Data was missing for one item for one individual for the OCQ; for the EDE-Q there were six individuals contributing a total 13 missing item responses; three individuals across five missing DRES responses; four individuals across six missing responses on the taste test rating forms. Missing data was replaced with prorated scores for the items within individuals. No outliers on the psychometric variables were identified when operationally defined as a z-score equal to or greater than 3.29 (Field, 2009).

Characteristics of Participants

Eighty-five people enrolled in the experiment but two were withdrawn, leaving sample size $n = 83$; one because of failure to comply with instructions by not consuming any chocolate, and one because of technical errors during the HRV recording. The mean age of the participants was 21.23 years ($SD = 5.09$). The majority of these participants were Caucasian (83.1%), followed by individuals who were Native Canadian (9.6%), other (4.8%), and South Asian (1.2%) descent. One participant did not report ethnicity. A small number of participants were married or in a common-law relationship (13.3%) or reported being either divorced or separated (1.2%). The remainder of the sample (85.5%) reported being single. Of the 83 participants, 78 (94%) were enrolled in a full-time academic program, while 5 (6%) participants reported enrolment in part-time studies.

Psychometric Variables

Descriptive information pertaining to the psychometric variables is presented in Table 1. Internal consistency indices of Cronbach's α range .77-.95. Two OCQ subscales Guilt and Avoidance and two EDE-Q subscales Eating Concern and Restraint possessed significant positive skew where $z_{skewness}$ exceeded 1.96 consistent with $p < .05$. These subscales were subjected to a natural log transformation which produced $z_{skewness}$ ranging -0.39 to -1.18, hence no longer significantly positively skewed. The log transformed scores of these four subscales were therefore utilized in all subsequent analyses.

Table 1

Scale Reliability Coefficients and Descriptive Statistics

Variables	*M*	*SD*	α	No. of items	Range: Potential	Range: Actual	$z_{Skewness}$
DRES	25.64	9.20	.92	10	10-50	10-46	0.28
EDE-Q							
Restraint	1.55	1.22	.78	5	0-6	0.0-5.2	2.06
Eating Concern	0.88	0.78	.64	5	0-6	0.0-3.0	3.05
Shape Concern	2.56	1.52	.92	8	0-6	0.1-5.6	0.36
Weight Concern	2.34	1.49	.85	5	0-6	0.0-5.4	1.09
Global	1.81	1.13	.95	23	0-6	0.0-4.5	1.13
OCQ							
Approach	24.90	10.17	.84	6	6-54	6.0-49.0	0.08
Guilt	23.02	12.64	.93	6	6-54	6.0-53.0	2.25
Avoidance	6.39	3.93	.77	2	2-18	2.0-17.0	2.53

Note. DRES= Dutch Restrained Eating Scale; EDE-Q= Eating Disorder Examination Questionnaire; OCQ= Orientation to Chocolate Questionnaire. $n = 83$.

Table 2 displays the inter-correlations among the psychometric variables along with chocolate consumption. Noteworthy are the low, non-significant associations between OCQ

Approach and chocolate consumption with all other psychometric variables. It appears that self-reported trait sentiments and behaviours related to dieting and body image are statistically unrelated to the act of ad libitum consumption of chocolate.

Table 2

Inter-Correlations Among Psychometric Variables

Variable	1	2	3	4	5	6	7	8	9	10
1. DRES										
EDE-Q										
2. Restraint	.80**									
3. Eating Concern	.62**	.62**								
4. Shape Concern	.66**	.66**	.75**							
5. Weight Concern	.71**	.71**	.75**	.90**						
6. Global	.78**	.83**	.84**	.94**	.95**					
OCQ										
7. Approach	.13	.20	.13	.13	.04	.13				
8. Guilt	.54**	.50**	.49**	.42**	.47**	.50**	.25*			
9. Avoidance	.26*	.34**	.19	.22*	.25*	.28*	.60**	.51**		
10. Chocolate consumption	-.14	-.11	.01	.05	.01	-.01	.11	-.12	.06	

Note. DRES= Dutch Restrained Eating Scale; EDE-Q= Eating Disorder Examination Questionnaire; OCQ= Orientation to Chocolate Questionnaire. $n = 83$. * $p < .05$; ** $p < .01$

To determine whether groups significantly differed on any of the psychometric variables, separate one-between groups ANOVAs were conducted for each variable with instructional set (crave, resist, no-instruction control) serving as the grouping variable. All of the nine obtained *F*s had $p > .17$, indicating that the three experimental groups did not differ on any of the psychometric variables.

Chocolate Consumption

According to hypothesis 1, participants instructed to resist chocolate during phase-2 induction and phase-3 challenge would consume more chocolate during the subsequent phase-4 taste test compared to those participants in the craving or no-instruction control conditions. To test this hypothesis, amount consumed in g was summed over the three different types of chocolate. Participants consumed $M = 23.6$ ($SD = 15.81$) g chocolate; range = 2.54 – 81.6 g, $z_{skewness} = 3.79, p < .0002$. Subsequent natural log transformation of g produced $z_{skewness} = -1.07$, $p > .14$ which corrected the significant positive skew in the data. The non-significant Levine's test on the natural log of g indicated there was homogeneity of variance among the three experimental groups, $F(2, 80) = 0.68$, $p = .511$. A one-between groups ANOVA on the natural log of g failed to produce a main effect for the independent variable of instructional set, $F(2, 80) = 1.25$, $p = .290$, $\eta^2 = .03$, observed power = .27. The means (with standard deviations in parentheses) were as follows: resist condition = 27.72 g (19.49), crave condition = 22.56 g (12.80), no-instruction condition = 20.93 (15.06). Contrary to hypothesis 1, instructional set had no impact upon the subsequent amount of chocolate consumed during the taste test.

Cardiac Function

Table 3 displays the descriptive statistics for the four untransformed cardiac parameters over each of the five phases of the experiment. HR expressed as beats per minute (bpm) was not significantly skewed at any of the five phases; all HR $z_{skewness}$ coefficients were within $\pm$ 1.96 corresponding to $p > .05$. Conversely, all three indices of HRV evidenced significant positive

Table 3

Descriptive Statistics of the Untransformed Cardiac Parameters Over the Phases of the Experiment

	Phase 1: Baseline	Phase 2: Induction	Phase 3: Challenge	Phase 4: Taste Test	Phase 5: Recovery
HR (bpm)	77.80 (10.83) [1.50]	77.93 (10.56) [1.01]	79.56 (9.65) [1.07]	85.40 (8.59) [0.75]	78.04 (9.71) [0.82]
LF/HF	1.57 (1.80) [10.40]	1.82 (1.68) [7.85]	2.00 (1.70) [6.60]	3.14 (1.99) [4.33]	1.95 (1.69) [11.51]
LF (ms^2)	879.08 (706.52) [11.12]	1074.71 (995.70) [9.31]	1142.90 (858.60) [7.17]	1204.73 (801.70) [6.18]	1384.54 (1818.53) [23.76]
HF (ms^2)	1182.06 (1285.37) [7.84]	1038.58 (1141.18) [7.91]	975.66 (966.84) [7.17]	591.52 (600.56) [8.92]	1289.65 (2621.59) [26.79]

Note: Mean (standard deviation) [$z_{skewness}$]. n = 83.

skew at each of the five phases. By subjecting these to the natural log transformation, the significant skew no longer remained in most instances except for HF at phases 1 and 3 (see Table 4). Table 5 presents the means (with standard deviations in parentheses) for the four cardiac parameters in each of the three instruction conditions over the five phases of the experiment.

According to hypothesis 2, participants in the resisting condition would experience lower HRV during phase-2 induction and phase-3 challenge compared to participants in the craving and no-instruction control conditions. A separate one-between multivariate analysis of variance (MANOVA) was conducted for each of the two phases to determine the effect of instruction on the four cardiac parameters. The instruction main effect proved to be non-significant both at phase 2, Wilks' $\Lambda = .84$, $F(8, 154) = 1.79$ $p = .084$, multivariate $\eta^2 = .09$, and at phase 3, Wilks' $\Lambda = .92$, $F(8, 154) = 0.88$ $p = .538$, multivariate $\eta^2 = .04$. Thus, contrary to hypothesis 2, instructional set produced no differential effect on cardiac function during the induction and challenge phases of the experiment.

In order to explore potential changing trends in the cardiac parameters over the phases of the experiment, a one-between (instruction), one-within (phase) mixed MANOVA was conducted. The analysis produced a non-significant main effect for instruction, Wilks' $\Lambda = .90$, $F(8, 154) = 1.0$, $p = .43$, multivariate $\eta^2 = .05$, and a non-significant Instruction X Phase interaction, Wilks' $\Lambda = .54$, $F(32, 130) = 1.45$ $p = .076$, multivariate $\eta^2 = .26$. The analysis did, however, produce a significant phase main effect, Wilks' $\Lambda = .13$, $F(16, 65) = 26.44$, $p < .001$, multivariate $\eta^2 = .87$, indicating there was a significant pattern of change across the cardiac parameters over the phases of the experiment.

Next, separate one-within univariate ANOVAs were performed for each of the four cardiac parameters to elucidate the point of change over the phases of the experiment. Mauchly's

Table 4

Descriptive Statistics of the Natural Log Transformed HRV Parameters Over the Phases of the Experiment

	Phase 1: Baseline	Phase 2: Induction	Phase 3: Challenge	Phase 4: Taste Test	Phase 5: Recovery
LF/HF (*ln*)	.00 (.95) [.29]	.26 (.83) [.32]	.38 (.82) [.09]	.94 (.67) [-1.60]	.40 (.73) [.43]
LF (*ln* ms^2)	6.53 (.73) [-1.58]	6.65 (.81) [-.06]	6.77 (.78) [-1.78]	6.89 (.65) [-.88]	6.85 (.88) [-.82]
HF (*ln* ms^2)	6.53 (1.15) [-2.07]	6.40 (1.14) [-1.91]	6.39 (1.10) [-2.34]	5.95 (.98) [-1.22]	6.45(1.20) [-.84]

Note: Mean (standard deviation) [$z_{skewness}$]. $n = 83$.

Table 5

Descriptive Statistics Cardiac Parameters Over the Phases of the Experiment As a Function of Experimental Condition

Variable by Group	Phase 1: Baseline	Phase 2: Induction	Phase 3: Challenge	Phase 4: Taste Test	Phase 5: Recovery
HR (bpm)					
Resist	77.80 (12.27)	77.98 (11.88)	80.34 (11.19)	84.63 (10.00)	77.12 (10.58)
Crave	76.56 (10.97)	77.40 (10.95)	78.48 (10.02)	85.23 (8.23)	78.00 (9.66)
Control	79.80 (9.31)	78.53 (8.98)	80.12 (7.63)	86.37 (7.78)	78.97 (9.21)
LF/HF (*ln*)					
Resist	-0.03 (0.93)	0.14 (0.76)	0.33 (0.94)	0.63 (0.74)	0.34 (0.82)
Crave	0.13 (1.02)	0.48 (0.83)	0.52 (0.71)	1.09 (0.53)	0.57 (0.62)
Control	-0.13 (0.88)	0.09 (0.87)	0.26 (0.82)	1.07 (0.68)	0.26 (0.75)
LF ([ms^2] *ln*)					
Resist	6.64 (0.58)	6.85 (0.80)	6.80 (0.76)	6.85 (0.70)	6.87 (0.91)
Crave	6.53 (0.78)	6.75 (0.77)	6.78 (0.89)	6.87 (0.72)	6.85 (0.79)
Control	6.43 (0.81)	6.35 (0.82)	6.74 (0.67)	6.97 (0.51)	6.83 (0.98)
HF ([ms^2] *ln*)					
Resist	6.68 (1.25)	6.71 (1.20)	6.47 (1.28)	6.23 (1.03)	6.52 (1.24)
Crave	6.39 (1.07)	6.27 (1.03)	6.26 (1.02)	5.78 (0.99)	6.28 (1.06)
Control	6.55 (1.17)	6.26 (1.21)	6.49 (1.03)	5.91 (0.89)	6.57 (1.34)

Note. Mean (standard deviation).

test revealed the sphericity assumption was violated in each case ($ps < .038$). Consequently, Greenhouse-Geisser corrected *df*s were utilized to gauge the level of statistical significance for each univariate statistical test (Field, 2009). Each test produced a significant phase main effect: HR, $F(3.30, 154) = 75.88$ $p < .001$, $\eta^2 = .49$; LF/HF, $F(3.61, 154) = 34.48$ $p < .001$, $\eta^2 = .30$; LF, $F(3.46, 154) = 7.14$ $p < .001$, $\eta^2 = .08$; and HF, $F(3.46, 154) = 18.23$ $p < .001$, $\eta^2 = .19$. Figures 2 through 5 depict these univariate phase main effects along with the results of simple (first) contrasts where each phase was compared to the phase-1 baseline. It is clear from Figure 1 that participants responded to phase-4 chocolate taste test with a precipitous rise in cardiac bpm that returned to baseline minutes later during phase-5 recovery. Similarly, Figure 3 illustrates the mirror image of this reactivity concerning the HF parameter of HRV caused by chocolate consumption that likewise returned to baseline during recovery. The pattern of reactivity is similar for both LF and LF/HF, though return to baseline is less complete in both instances. Recent research has also discovered prolonged recovery for LF and LF/HF (Papousek et al., 2010).

Table 6 displays the inter-correlations among the four cardiac parameters. Noteworthy is similarity in both direction and magnitude of association among the parameters across the phases of the experiment. Of further interest is the inverse relationship of HR to both LF and HF, with the latter being most strongly associated with HR over all phases, *r*s range -.65 to -.73.

Exploratory Analysis of Cardiac Reactivity and Recovery

It is apparent that consuming chocolate led to an overall 9.8% increase in HR over baseline among participants. Significant changes over baseline in HRV was also observed for LF, HF, and the ratio LF/HF; 37%, 50%, and 100%, respectively. Given that a high LF/HF ratio is to be interpreted as low HRV, the latter figure points to a 100% reduction in HRV. Previous research has investigated the ability of certain individual difference variables like trait positive

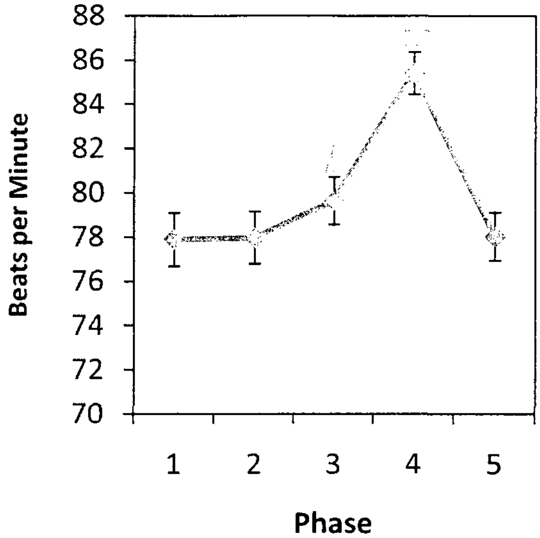

Figure 2. Heart rate over the five phases of the experiment. Error bars represent standard errors. ☆ $p < .05$ compared to phase 1 baseline.

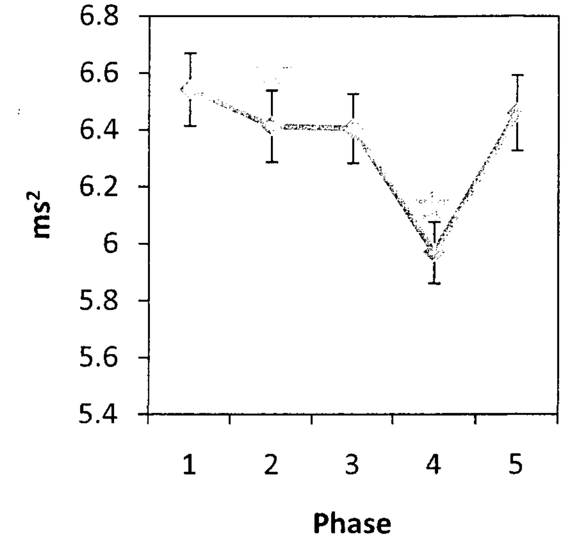

Figure 3. Log transformed absolute power of the high frequency band.

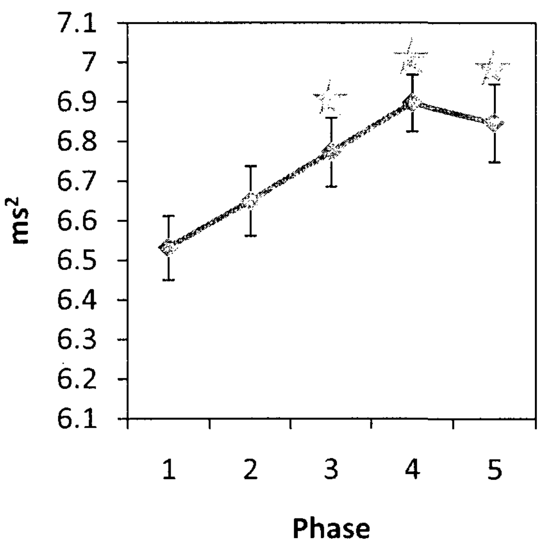

Figure 4. Log transformed absolute power of the low frequency band.

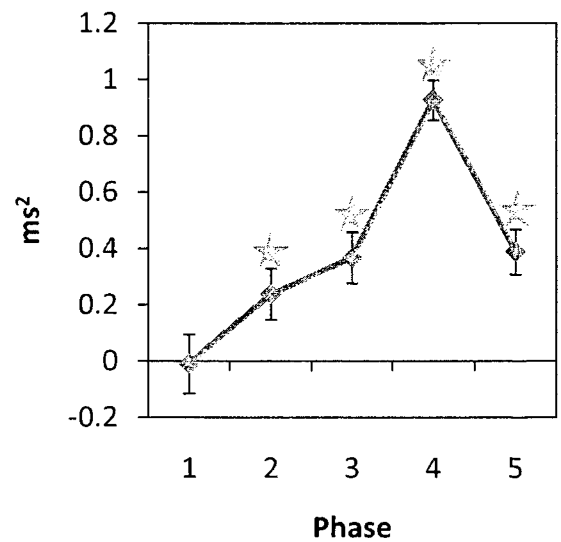

Figure 5. Log transformed ratio between low frequency and high frequency band power.

Table 6

Inter-correlations of Cardiac Parameters

	Phase 1: Baseline		
	HR	LF/HF	LF
LF/HF	.51*		
LF	-.36*	.08	
HF	-.65*	-.77*	.57*

	Phase 2: Induction		
	HR	LF/HF	LF
LF/HF	.50*		
LF	-.45*	.03	
HF	-.68*	-.70*	.69*

	Phase 3: Challenge		
	HR	LF/HF	LF
LF/HF	.47*		
LF	-.45*	.05	
HF	-.67*	-.71*	.67*

	Phase 4: Taste Test		
	HR	LF/HF	LF
LF/HF	.45*		
LF	-.53*	.10	
HF	-.66*	-.75*	.73*

	Phase 5: Recovery		
	HR	LF/HF	LF
LF/HF	.37*		
LF	-.69*	-.11	
HF	-.73*	-.69*	.80*

Note: * $p < .01$

affect (Papousek et al., 2010), trait rumination (Key et al., 2008), and anger inhibition (Vella & Friedman, 2009) to the predict psychophysiological reactivity including HR, HRV, blood pressure within the context of various interpersonal stressor paradigms. In a similar vein, an exploratory analysis was herein undertaken to examine self-reported individual differences in attitudes and behaviours related to dieting and body image for their potential to predict the magnitude of cardiac reactivity to chocolate consumption that was observed among participants. Linden et al. (1997) highlight that it is essential for researcher's to report both cardiac reactivity scores and recovery scores to elucidate the underlying physiological mechanisms in response to a stressor. Consequently, similar exploratory analyses of recovery to baseline following chocolate consumption were also undertaken.

Cardiac Reactivity. Hierarchical multiple regression analyses were performed to examine if the psychometric variables would predict cardiac reactivity across the four cardiac parameters. Reactivity is conventionally defined as the physiological change from baseline in response to a stressor (Key et al., 2008; Linden et al., 1997). In the present study, reactivity change scores were mathematically computed by subtracting the phase-1 baseline from the phase-4 chocolate taste test for each of the four cardiac parameters.

Table 7 displays the results of the hierarchical multiple regression analyses predicting cardiac reactivity. To control for potential pharmacological and/or psychological effects of consuming chocolate on cardiac function, this variable was entered in step 1. The psychometrics that measure an individual's propensity to possess body image concerns and dieting behaviours, DRES and EDE-Q, were entered into step 2. To examine if an individual's sentiment towards chocolate added further predictive ability, the psychometrics that measured attitudes and behaviours specifically toward chocolate, the OCQ, were entered in step 3.

Table 7

Hierarchical Multiple Regression Analyses Predicting Cardiac Reactivity

	Cardiac Parameters							
	ΔHR		ΔHF		ΔLF		ΔLF/HF	
Predictors	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	.08**		.02		.01		.00	
Chocolate Consumption		.27*		-.11		-.11		.00
Step 2	.01		.02		.03		.03	
DRES		-.11		.01		-.20		-.19
EDE-Q Weight Concern		.23		-.29		.05		.31
EDE-Q Shape Concern		-.11		.10		-.18		-.25
EDE-Q Eating Concern		-.07		.21		.09		-.11
EDE-Q Restraint		.08		-.04		.21		-.23
Step 3	.01		.03		.02		.04	
OCQ Approach		.11		-.12		.14		.24
OCQ Guilt		-.03		.03		-.01		-.04
OCQ Avoidance		.01		.20		.04		-.15
Total R^2	.10		.06		.06		.06	

Note. HR = Heart Rate; HF = Log transformed absolute power of the high frequency band; LF = Log transformed absolute power of the low frequency band; LF/HF = Log transformed ratio between low frequency and high frequency band power; DRES = Dutch Restrained Eating Scale; EDE-Q = Eating Disorder Examination Questionnaire; OCQ = Orientation to Chocolate Questionnaire. n = 83. * $p < .05$; ** $p < .001$

Certain parametric assumptions of regression were evaluated (Field, 2009). Specifically, the Durbin-Watson tests for the assumption of independent errors; that is, the residual terms for any set of observations should be uncorrelated. The obtained test values ranged from a low of 1.67 to a high of 2.52 across the eight separately conducted regression analyses. The values lie within the acceptable range of 1 to 3, suggesting the assumption of independent errors is tenable. Regarding the assumption of homoscedasticity, examination of separate scatterplots of the standardized predicted values and the standardized residuals suggests comparable variance in the residuals at across levels of the predictors. Finally, examination of both histograms and normal P-P plots suggests the assumption of the normality of residuals is tenable.

HR reactivity was the first criterion variable to be examined in the regression model outlined above. The chocolate consumption variable entered at step 1 was significant, $F(1, 81) = 6.92$, $p < .01$ with an R^2 value of .08 which indicated that 8% of the variance in the criterion variable, HR reactivity, may be explained by chocolate consumption. No other variable predicted HR reactivity. Furthermore, none of the psychometric variables were able to significantly predict variability in any of the remaining regression analysis involving the criterion variables of HF, LH, and LF/HF reactivity (see Table 7).

Cardiac Recovery. Hierarchical multiple regression analyses were also employed to examine if the psychometric variables including chocolate consumption would predict cardiac recovery across the four cardiac parameters. Cardiac recovery is conventionally defined as the post-stress rest period after a stressor wherein physiological functioning is expected to return to baseline levels (Key et al., 2008; Linden et al., 1997). Cardiac recovery scores were mathematically computed by subtracting the phase-5 recovery period from phase-1 baseline across the four cardiac parameters. Higher change scores correspond to less cardiac recovery.

Table 8 displays the results of the hierarchical multiple regression analyses predicting cardiac recovery. The predictor variables were identical to the first set of hierarchical multiple regressions reported above with one exception: Cardiac reactivity was entered into step 1 to statistically remove the influence of reactivity on recovery (Key et al., 2008; Linden et al., 1997). As would be expected, reactivity significantly predicted recovery in all four regressions in which higher initial reactivity is associated with higher recovery scores, meaning less complete return to baseline in the time of 10 min that was allotted to this phase. The only criterion variable for which any of the psychometrics added further unique predictive ability was LF/HF recovery in which the step 3 psychometrics were statistically significant, $F\ (5, 75) = 2.51$, $p = .04$ with an R^2 value of .09. Two of five tested psychometrics were statistically significant in this step; EDE-Q Weight Concerns, $\beta = .77$, $t(72) = 3.34$, $p < .001$, and EDE-Q Shape Concerns, $\beta = -.42$, $t(72) = -1.98$, $< .05$. However, these two predictor variables were themselves highly correlated, r = .91, p < .001, suggesting a problem with collinearity that can obscure interpretation of the findings relevant to these two predictors. Specifically, obtaining unique estimates of the regression coefficients is not attainable because the coefficients are interchangeable. In an attempt to avert this problem of collinearity, the regression was re-run with EDE-Q Shape Concerns removed from the analysis. The resulting R^2 for step 3 dropped from .09 to .06 and was no longer statistically significant, $F\ (4, 76) = 2.12$, $p = .09$.

Summary. Taken together, the results of these exploratory analyses suggest that the large effect sizes of chocolate consumption upon subsequent cardiac reactivity and recovery could not be predicted from individual differences among participants' attitudes and behaviours regarding eating behaviour and body image. Only the unitary observation of the amount of chocolate consumed significantly predicted greater initial reactivity of heart rate.

Table 8

Hierarchical Multiple Regression Analyses Predicting Cardiac Recovery

	Cardiac Parameters							
	ΔHR		ΔHF		ΔLF		ΔLF/HF	
Predictors	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	.40**		.26**		.40**		.40**	
Cardiac reactivity		.58**		.51**		.64**		.59**
Step 2	.02		.00		.00		.00	
Chocolate Consumption		.16		-.04		.04		.05
Step 3	.02		.02		.06		.09*	
DRES		-.16		-.01		-.17		-.19
EDE-Q Weight Concern		.11		-.30		.52		.77**
EDE-Q Shape Concern		-.06		.22		-.22		-.42*
EDE-Q Eating Concern		.10		.02		-.16		-.16
EDE-Q Restraint		.03		.08		.03		-.01
Step 4	.01		.02		.01		.00	
OCQ Approach		-.05		-.10		-.02		.07
OCQ Guilt		.06		-.11		-.10		-.01
OCQ Avoidance		.11		-.01		-.02		.01
Total R^2	.45**		.30**		.47**		.49**	

Note. HR = Heart Rate; HF = Log transformed absolute power of the high frequency band; LF = Log transformed absolute power of the low frequency band; LF/HF = Log transformed ratio between low frequency and high frequency band power; DRES = Dutch Restrained Eating Scale; EDE-Q = Eating Disorder Examination Questionnaire; OCQ = Orientation to Chocolate Questionnaire. n = 83. * $p < .05$; ** $p < .001$

Discussion

The present study sought to elucidate aspects of self-regulatory processes with respect to food intake. A small literature suggests that attempts to actively suppress thoughts about the commission of a specific behaviour can lead to an increase in the likelihood of subsequently engaging in such behaviour (Macrae et al., 1994; Palfai, Colby, Monti, & Rohsenow, 1997). Eskine (2008) observed that women who were experimentally instructed to resist thinking about chocolate subsequently consumed more relative to a no-instruction control; a phenomenon known as the behavioural rebound effect. The present study was unsuccessful in replicating this observation. Several possibilities need to be considered in attempting to understand the failure.

First, any failure to reject the null hypothesis must consider the statistical issue of power, itself influenced by a confluence of factors including effect size and sample size. When chocolate consumption was operationally defined as amount of chocolate consumed in g, the resulting one-between ANOVA revealed a small effect size ($\eta^2 = .03$) for the independent variable of instructional set. Indeed, overall power of this statistical test was a trivial 27%. Inputing these two factors into a power calculation reveals that a total sample size of 2,742 participants would be required of an exact replication of current methodology in order to reject the null hypothesis.

Other considerations for failure to demonstrate a behavioural rebound effect in the current study must necessarily turn to a discussion of methodological differences between this experiment and the one by Erskine (2008) upon which it was essentially predicated. There are three areas of methodological divergence between the two studies; (a) characteristics of the participants, (b) method of experimental induction of resistance, and (c) method of ascertaining rebound through the taste test. Regarding participants, Erskine purposely excluded females who were dieting for reasons that he did not articulate, although he did cite evidence in which dieting is associated with increased intrusions by thoughts about food (Mann & Ward, 2001). The present study made no such exclusion. Even so, it is difficult to understand how active dieters recruited into the present study would differentially respond to the independent variable by obscuring (suppressing) an otherwise significant experimental effect of instructional set. What we do know is that dieting status was unrelated to the primary dependent variable of chocolate consumption. Specifically, none of the psychometrics that measure attitudes and behaviours toward eating and body image significantly correlated with chocolate consumption when analyzed within each of the experimental condition, and again when considered over the entire sample. A more definitive understanding of the potential for a suppressing effect of dieting status may be revealed by a measure of the degree of thought intrusiveness regarding chocolate as participants underwent the induction. This may determine whether dieting status is differentially associated with ability to resist chocolate. In the absence of such, this methodological divergence remains a candidate for explaining current failure to replicate. Future research in this area would do well to consider the value of including dieting status as an independent variable and specifically measure in some manner the extent to which dieters are similar to, or different from, non-dieters in their ability to actively resist intrusiveness about thoughts of food.

The second methodological divergence between the two studies concerns the precise manner of experimental induction of resistance. In the Erskine (2008) study, participants engaged in a thought sampling task whereby for 5 min they were to instructed freely articulate their stream of consciousness while purposely avoiding any thoughts related to the upcoming chocolate taste test task they were about to partake in. In the control condition participants were merely instructed to freely associate out loud without explicit instruction regarding chocolate.

All participants pressed a buzzer each time they experienced a thought about chocolate whether or not it was verbalized. Interestingly, this manipulation did not have the intended effect upon frequency of intrusive thoughts of chocolate: The two conditions did not significantly differ in the number of chocolate thoughts. They did, however, differ in amount of chocolate subsequently consumed in a bogus taste test, whereby resisters consumed significantly more than controls.

The current methodology likewise instructed participants to resist thoughts of chocolate, not of the impending taste test as in Erskine (2008), but of the stimuli that they were directly being exposed to during phase 2 (pictures of chocolate) and phase 3 (actual chocolate bars) of the present study. In so doing, it may have been too onerous a task for participants to resist cognitive mentation on the very stimuli they were being exposed to in the moment. In short, they may not have been able to successfully resist thinking of chocolate. Unfortunately, the present study did not include any methodological check on the ability of the experimental manipulation to be successful in having participants resist. Erskine's informal poll of participants suggests they resisted "to best of their ability" (p. 417). At any rate, this methodological issue remains a contender as to why the present study failed to replicate Erskine's behavioural rebound effect concerning chocolate consumption.

The third point of methodological divergence involves variations in the taste test paradigm utilized to ascertain chocolate consumption that essentially amounts to slight differences in type of chocolate offered and type of instructions given about how to sample and complete the taste test rating forms. The main similarity between the methodologies concerns the use of deception. Participants were informed that the intent of the taste test was to ascertain "how thinking can affect taste preferences" (Erskine, 2008, p. 417), and "cardiac responses relate to food preferences such as chocolate" (current study). In both cases, the real intent of observing amount of chocolate consumed was not revealed to participants. Erskine's poll of participants revealed that only 1% correctly guessed the true purpose of the taste test and were therefore subsequently omitted from the analysis. Unfortunately, such a manipulation check was not conducted in the present study. Thus, the extent to which participants consciously moderated their chocolate consumption for concerns about being monitored cannot be ascertained or excluded as a contender for understanding present failure to replicate Erskine's behavioural rebound.

The second purpose of the present study was to investigate HRV as a potential biomarker for lapses in self-regulatory behaviour. Given that (a) resisting leads to behavioural rebound as demonstrated by Erskine (2008), and (b) that rebound may be considered to represent a behavioural lapse in self-regulation, it was not unreasonable to hypothesize that (c) participants instructed to resist chocolate should demonstrate a concomitant loss in HRV during those parts of the experiment which instructs them to do so; that is, during phase 2 induction and phase 3 challenge. However, the present study failed to demonstrate a differential effect of instructional set upon chocolate consumption (hypothesis 1) or HRV (hypothesis 2). It could be that failure to demonstrate the latter was a direct result of failure to demonstrate the former; that is, no lapse in behavioural self-regulation means no prior alteration in HRV, its reputed underlying biological substrate (Segerstrom & Solberg Nes, 2007).

What is most intriguing about the present study is that HRV did indeed alter, and dramatically so, not at the place expected in the experimental timeline (i.e., during resistance induction), but in the final 4 min of the phase-4 taste test. Here we observed reactivity in HR over baseline by 10%. Reactivity in HRV was even more dramatic, ranging 37 – 100%

depending upon the specific index of HRV. In consideration of the fact the typical participant consumed about 24 g of chocolate (ranging 3 – 81 g), equivalent to 27 pieces of candy and arguably more than would be required of them in order to complete the taste test rating forms, it would appear that many participants demonstrated a lapse in behavioural self-regulation.

Self-regulatory theory posits that lapses in self-regulation are a consequence of prior exertion in, and eventual exhaustion of, self-regulatory effort (Muraven & Baumeister, 2000; Muraven et al., 1998). It could be that the present study's phase-2 induction and phase-3 challenge was effortful and set the stage for behavioural dysregulation. Consider the fact that 57 of 83 participants, those in the resisting and craving conditions, viewed and interacted with chocolate. Also consider the fact that for 5 min during the phase-3 challenge these participants intimately interacted with chocolate (smelled, touched, manipulated) while specifically instructed to refrain from eating it. Such actions might be construed of as expenditure of effort to engage in self-regulation. After all, as depicted in Figure 5, LF/HF begins to increase during phase 2 and 3, meaning that HRV begins to drop, eventually giving way to collapse at phase 4 post-taste test.

Alternatively, it could be that the phase-4 chocolate taste test itself was viewed by participants as a stressor which caused a drop in HRV. Chocolate is viewed as a highly desirable and craved substance (Lafay et al. 2001; Tiggemann & Kemps 2005) and yet, compared to men, women report less positive affect subsequent to indulgence (Weingarten & Elston, 1990). Feelings of guilt and ambivalence following chocolate consumption have also been reported and are hypothesized to arise due to the fact that the sensory appeal of chocolate must be weighed against the potentially unhealthy nutritional properties such as high fat and sugar content (Cartwright & Strizle, 2008). Perhaps eating chocolate led to the feeling of guilt which in turn led to biological dysregulation. Segerstrom and Solberg Nes (2007) also found that consuming chocolate lead to a 25% drop in HRV. Future investigations should research the psychology of eating chocolate to ascertain causal mechanisms of biological dysregulation.

Although it is plausible that psychological factors are responsible for the observed cardiac reactivity following the phase-4 taste test, the pharmacological properties of chocolate cannot be overlooked. The pharmacologically active compounds in chocolate include theobromine, a metabolite of caffeine, and caffeine itself (Smit et al, 2004). Both theobromine and caffeine belong to a class of alkaloid molecules known as methylxanthines. Theobromine and caffeine are present in dark chocolate and to a lesser extent in milk chocolate (Smit et al.). The present study discovered cardiac reactivity immediately following chocolate consumption. However, research examining the impact of the immediate psychostimulant effects of theobromine and caffeine on the heart is both limited and mixed. For instance, Baron et al. (1999) found that 2 hours after healthy young adults consumed a comparatively large dose of dark chocolate (i.e., 1.5 g/kg of their body weight), participants' theobromine levels did not change. However, this study did not investigate milk chocolate or the immediate effects of consuming chocolate.

Smit el al. (2004) examined the immediate psychostimulant effects of milk and dark chocolate on cognitive function and discovered that participants who consumed dark chocolate had faster reaction times on both a simple reaction task and rapid visual information processing task compared to white chocolate controls. Conversely, consuming milk chocolate produced faster reaction times on only the latter task. Although these findings appear to suggest that consuming milk chocolate may have psychostimulant effects, changes in cardiac parameters were not examined. Therefore, future studies should investigate the immediate psychostimulant effects of chocolate on the heart to ascertain the underlying causal mechanisms for the observed phase-4 cardiac reactivity.

Other noteworthy aspects of the current study that were not initially anticipated include comparable cardiac recovery scores and cardiac parameter inter-correlations to that of other empirical research. For instance, Papousek et al. (2010) discovered that subsequent to a stress paradigm in which first-year undergraduate students answered a difficult statistics problem in front of a video camera, HR and HF returned to baseline during the recovery period whereas LF and LF/HF did not. Recovery in the present study mirrors this finding which may suggest that consuming 24 g of chocolate may have served as an environmental challenge akin to answering a difficult statistics question aloud into a camera. Other studies utilizing an environmental challenge also reveal rapid recovery of HR and HF compared to LF and LF/HF (Chatkoff et al., 2009; Maunder et al., 2006).

Furthermore, Papousek et al. (2010) measured HR and HRV indices using a two-lead electrocardiogram (ECG) whereas the present study used the Polar RS800 heart rate monitor. Yet, the present study found inter-correlations among the cardiac parameters that are nearly identical in magnitude and direction to those found by Papousek et al. Despite the fact that both the present study and Papousek et al. did not control for respiration rate, which can influence HRV (Pagani et al., 1991), the similarity of the inter-correlations may suggest that both the ECG and the Polar S810 are good measures of cardiac parameters.

In summary, the present study discovered that participants experienced cardiac responsiveness after the phase-4 chocolate taste test regardless of experimental condition. The observed cardiac reactivity to chocolate is intriguing and warrants further study to ascertain causal mechanisms which may involve specific pharmacological properties and/or psychological self-regulatory process implicated in the ingestion of highly palatable foods.

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Appendix A

Initial Email Contact to all Potential Participants

Dear Potential Participant,

I am a graduate student in Clinical Psychology and am currently conducting a study for my Master's thesis under the supervision of Dr. Ron Davis in the Department of Psychology. We are examining cardiac responses related to food preferences, namely chocolate.

I am inviting females to participate in this study which will require approximately 60 minutes of your time. One bonus point toward your Introductory Psychology final grade will be awarded for your participation.

Participation in this study requires that you sample chocolate therefore it is vital that you do not have any allergies to chocolate or peanut butter. Participation also requires that you abstain from eating any food or drinking any caffeinated beverages for at least 1 hour prior to visiting our lab to participate in the study.

The available time slots for participation are listed below. Please be aware of the fact that time slots are offered on a first-come-first-serve basis. If you are interested in participating in this study, please respond to this E-mail as quickly as possible to ensure that you reserve a spot that is convenient for you (lblanche@lakeheadu.ca).

Sincerely,

Loretta Blanchette, B.A. (Hons.)
M.A. Clinical Psychology Candidate
Lakehead University, Thunder Bay, ON
lblanche@lakeheadu.ca

Appendix B

Participant Information Sheet

Dear Participant,

Thank you for your interest in this study. Under the supervision of Dr. Ron Davis, I will be conducting a study to investigate cardiac responses related to food preferences including the actual tasting of chocolate.

If you agree to participate in this study, your cardiac responses will be measured while you view images on a T.V. screen. In addition, you will be asked to participate in a taste test of three types of chocolate and subsequently fill out a few of questionnaires related to your eating attitudes and behaviours. Your participation involves a 1-hour visit to our lab during which you will be fitted with a heart rate monitor involving the placement of a chest strap.

Your participation in this study is completely voluntary and you may withdraw from it at any time without penalty. All formation that you provide will be kept completely confidential. Only Dr. Ron Davis, myself, and a research assistant will be permitted to view your information. Your name will only be used to ensure that you receive a bonus mark for the Introductory Psychology course. All of the information that you provide will be assigned a code and will be securely stored at Lakehead University for 5 years, as per University regulations. In addition, your identifying information will be kept completely confidential in reports of results and publications.

The Research Ethics Board (REB), which is located in the Office of Research at Lakehead University, has approved this study. If you have any questions regarding this research feel free to contact the REB at (807) 343-8283.

A risk associated with this study is the possibility that thinking about some personal issues may bring about some psychological concerns. If at any point during or after this study, you have concerns feel free to contact the Student Health and Counseling Centre at 343-8361 (UC 1007). Also, feel free to contact myself and/or Dr. Ron Davis with any questions that you might have. Thank-you again for your interest and help with this study.

Sincerely,

Loretta Blanchette, B.A. (Hons.)
M.A. Clinical Psychology Candidate
Lakehead University, Thunder Bay, ON
E-mail:lblanche@lakeheadu.ca
Phone: (807) 472-1607

Dr. Ron Davis, C. Psych.
Associate Professor of Psychology
Lakehead University, Thunder Bay, ON
E-mail: ron.davis@lakeheadu.ca
Phone: (807) 343-8646

Consent to Participate

By providing my name, student number, and E-mail, I indicate that I have read the previous "Participant Information Sheet" and that I wish to participate in this study which is conducted by Loretta Blanchette and under the supervision of Dr. Ron Davis. I understand that any questions that I might have about my participation can be answered by Loretta Blanchette and/or Dr. Ron Davis. Providing my identifying information below, I understand and agree to the following:

1. I understand the information on the "Participant Information Sheet".
2. I agree to participate in this study.
3. I am a volunteer and can withdraw at any time from this study without penalty or consequence.
4. I may choose not to answer any question asked in the questionnaires without penalty or consequence.
5. There are no anticipated physical risks associated with participation in this project. Should I experience any psychological distress or discomfort, I am entitled to a list of counseling resources from the researcher.
6. My data will remain confidential and will be securely stored in the Department of Psychology at Lakehead University for 5 years, as per University regulations.
7. My information will remain anonymous should any publications or public presentations come out of this study.
8. I may receive a summary of this research study upon completion of this study.
9. I give my permission to be contacted by telephone and/or E-mail for the purpose of participation in this study.

Please provide your information below.

____
Full Name *(please print)*

____
Date

____
Signature *(please sign)*

____
E-mail

____
Student Number

____
Phone

____
Name of Psychology 1100 Professor

Appendix C

Demographic Questionnaire

Marital status (check one):

Married/common law______ Divorced/Separated_______ Single______
Widowed______

Age: _______

What is your ethnic background (check one)?

Caucasian____ South Asian____ Hispanic____ African-Canadian_____
European____ Native-Canadian______ East Asian____

Other (Please specify)______________

School Enrolment: Full time student _______ Part time student ______

What academic program(s) are you in? __________________________________

What is/are your major(s)? ____

Appendix D

The Orientation to Chocolate Questionnaire – Revised

This questionnaire relates to YOUR ATTITUDES towards chocolate in the LAST MONTH. Please indicate how much you agree with the statements below by circling the number corresponding most closely to your attitude during the LAST MONTH. Your answers may range from AGREE NOT AT ALL (1) with the statement to AGREE VERY STRONGLY (9) with the statement.

I AGREE WITH THIS STATEMENT…

		Not At All								**Very Strongly**
1.	I wanted to eat chocolate as soon as I had the chance.	1	2	3	4	5	6	7	8	9
2.	I deliberately occupied myself so I would not want chocolate.	1	2	3	4	5	6	7	8	9
3.	I liked to indulge in chocolate.	1	2	3	4	5	6	7	8	9
4.	I felt guilty after eating chocolate.	1	2	3	4	5	6	7	8	9
5.	I considered myself weak when I gave in to my chocolate cravings.	1	2	3	4	5	6	7	8	9
6.	My desire to have some chocolate seemed overwhelming.	1	2	3	4	5	6	7	8	9
7.	I felt unhealthy after I'd eaten chocolate.	1	2	3	4	5	6	7	8	9
8.	I wanted to eat chocolate so much that one bite would not have been enough.	1	2	3	4	5	6	7	8	9
9.	I did things to take my mind off chocolate.	1	2	3	4	5	6	7	8	9
10.	I felt dissatisfied with myself after eating chocolate.	1	2	3	4	5	6	7	8	9
11.	I was thinking about chocolate a lot of the time.	1	2	3	4	5	6	7	8	9

12.	After eating chocolate I often wished I hadn't.	1	2	3	4	5	6	7	8	9
13.	I usually found myself wanting chocolate in the afternoons.	1	2	3	4	5	6	7	8	9
14.	I felt unattractive after eating chocolate.	1	2	3	4	5	6	7	8	9

15. In the LAST MONTH, how often did you eat chocolate? Please tick (✓) only one box:

Never. ☐
Once or twice ☐
Once a week ☐
Twice a week ☐
3-5 times a week ☐
Almost every day ☐
Every day ☐

Appendix E

Eating Disorder Examination - Questionnaire

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 hours 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
6. ...Has thinking about food or its calorie content made it much more difficult to concentrate on things you are interested in; for example, read, watch TV, or follow a conversation?	0	1	2	3	4	5	6
7. ...Have you been afraid of losing control over your eating?	0	1	2	3	4	5	6
8. ...Have you had episodes of binge eating?	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
9. ...Have you eaten in secret? (Do not count binges.)	0	1	2	3	4	5	6
10. ...Have you definitely wanted your stomach to be flat?	0	1	2	3	4	5	6
11. ...Has thinking about shape or weight made it more difficult to concentrate on things you are interested in; for example, read, watch TV, or follow a conversation?	0	1	2	3	4	5	6
12. ...Have you had a definite fear that you might gain weight or become fat?	0	1	2	3	4	5	6
13. ...Have you felt fat?	0	1	2	3	4	5	6

14. …Have you had a strong desire to lose weight?	0	1	2	3	4	5	6

OVER THE PAST FOUR WEEKS (28 DAYS)…….

15. …On what proportion of times that you have eaten have you felt guilty because the effect on your shape or weight? (Do not count binges.) (Circle the number which applies.)

0. None of the times
1. A few of the times
2. Less than half the times
3. Half the times
4. More than half the times
5. Most of the times
6. Every time

16. … Over the past four weeks (28 days), have there been any times when you have eaten what other people would regard as an unusually large amount of food given the circumstances? (Please circle appropriate number). **0- NO** **1- YES**

17. …How many such episodes have you had over the past four weeks? (Please write the appropriate number.) ________

18. ….During how many of these episodes of overeating did you have a sense of having lost control? ________

19. ….Have you had other episodes of eating in which you have had a sense of having lost control and eaten too much, but have not eaten an unusually large amount of food given the circumstances? **0- NO** **1- YES**

20. … How many such episodes have you had over the past four weeks? ________

21. ….Over the past four weeks have you made yourself sick (vomit) as a means of controlling your shape or weight? **0---NO** **1--- YES**

22. ….How many times have you done this over the past four weeks? ________

23. ….Have you taken laxatives as a means of controlling your shape or weight? **0--- NO** **1--- YES**

24. ….How many times have you done this over the past four weeks? ________

25. ….Have you taken diuretics (water tablets) as a means of controlling your shape or weight? **0--- NO** **1--- YES**

26. ....How many times have you done this over the past four weeks? ________

27. ....Have you exercised hard as a means of controlling your shape or weight?
0--- NO
1--- YES

28. ....How many times have you done this over the past four weeks? ________

OVER THE PAST FOUR WEEKS (28 DAYS)...........

(Please circle the number which best describes your behaviour)

	NOT AT ALL		SLIGHTLY		MODERATELY		MARKEDLY
29. ....Has your weight influenced how you think about (judge) yourself as a person?	0	1	2	3	4	5	6
30. ....Has your shape influenced how you think about (judge) yourself as a person?	0	1	2	3	4	5	6
31. ....How much would it upset you if you had to weigh yourself once a week for the next four weeks?	0	1	2	3	4	5	6
32. ....How dissatisfied have you felt about your weight?	0	1	2	3	4	5	6
33. ....How dissatisfied have you felt about your shape?	0	1	2	3	4	5	6
34. ....How concerned have you been about other people seeing you eat?	0	1	2	3	4	5	6

OVER THE PAST FOUR WEEKS (28 DAYS)...........

(Please circle the number which best describes your behaviour)

	NOT AT ALL		SLIGHTLY		MODERATELY		MARKEDLY
35 ....How uncomfortable have you felt seeing your body; for example, in the mirror, in shop window reflections, while undressing or taking a bath or shower?	0	1	2	3	4	5	6
36....How uncomfortable have you felt about others seeing your body; for example, in shared changing rooms, when swimming or wearing tight clothes?	0	1	2	3	4	5	6

37. What is your height? ______inches or ______cm (guess if you do not know)

38. What is your weight? ______lbs or ______kg (guess if you do not know)

Appendix F

Dutch Restrained Eating Scale

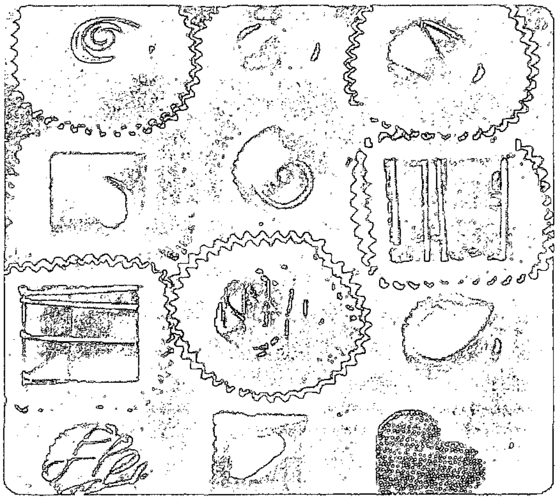
Please indicate which rating best applies to you by circling the response:

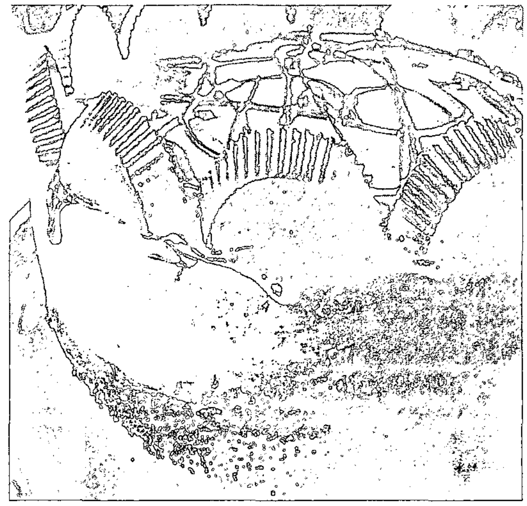
1 = Never **2** = Rarely; **3** = Sometimes; **4** = Often; **5** = Very Often

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

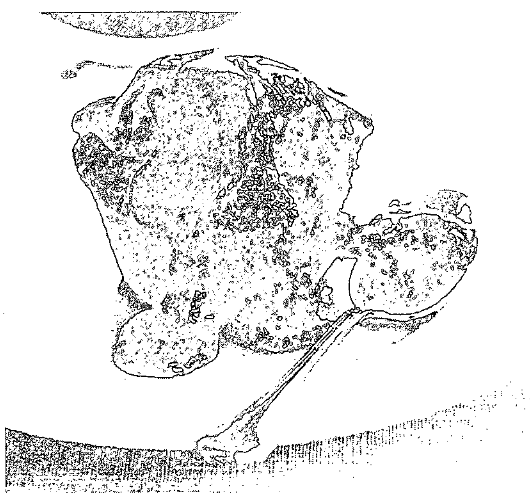
Appendix G

Sample of Food Images





CHOCOLATE



Appendix H

Candy Taste Rating Form

Please rate each cookie (candy) on the following dimensions on a scale of 1-10
(1 = terrible, 5 = average, 10 = excellent)

Candy A

1. Texture

   1 2 3 4 5 6 7 8 9 10

2. Flavour

   1 2 3 4 5 6 7 8 9 10

3. Fragrance

   1 2 3 4 5 6 7 8 9 10

4. Sweetness

   1 2 3 4 5 6 7 8 9 10

5. Crunchiness

   1 2 3 4 5 6 7 8 9 10

6. Overall rating

   1 2 3 4 5 6 7 8 9 10

7. How much do you like the candy?

   1 2 3 4 5 6 7 8 9 10

Score (to be completed by the experimenter)

Candy B

1. Texture

   1 2 3 4 5 6 7 8 9 10

2. Flavour

   1 2 3 4 5 6 7 8 9 10

3. Fragrance

   1 2 3 4 5 6 7 8 9 10

4. Sweetness

   1 2 3 4 5 6 7 8 9 10

5. Crunchiness

   1 2 3 4 5 6 7 8 9 10

6. Overall rating

   1 2 3 4 5 6 7 8 9 10

7. How much do you like the candy?

1 2 3 4 5 6 7 8 9 10

Score (to be completed by the experimenter)

Candy C

1. Texture

1 2 3 4 5 6 7 8 9 10

2. Flavour

1 2 3 4 5 6 7 8 9 10

3. Fragrance

1 2 3 4 5 6 7 8 9 10

4. Sweetness

1 2 3 4 5 6 7 8 9 10

5. Crunchiness

1 2 3 4 5 6 7 8 9 10

6. Overall rating

1 2 3 4 5 6 7 8 9 10

7. How much do you like the candy?

1 2 3 4 5 6 7 8 9 10

Score (to be completed by the experimenter)

Appendix I

Below is a list of agencies that offer mental health services for your information. Thank you again for your participation in this study.

1. **Lakehead University Student Health and Counselling Centre** (807-343-8361)
   Located across from Security, near the Agora and University Centre Theatre. Personal counselling for students covering a wide variety of issues.

2. **Family Services Thunder Bay** (807-684-1880)
   A not-for-profit organization providing confidential counselling, advocacy, education, and support for individuals and families in Thunder Bay. Counsellors provide comprehensive help for a wide variety of issues such as grief and coping, substance use, credit and financial problems, anger, anxiety, depression, and past experiences of violence. Fees are based upon individual circumstances and no person will be denied service due to an inability to pay.

3. **Eating Disorder Program** (St. Joseph's Care Group). (807-343-2400)
   A multidisciplinary team, which provides assessment and treatment to individuals with Anorexia Nervosa, Bulimia Nervosa, and Eating Disorder Not Otherwise Specified. A physician's referral is required for admission to the program.

4. **Personal Development Centre** (St. Joseph's Care Group). (807-343-2400)
   An adult out-patient program which offers and innovative, multi-disciplinary approach to treating a variety of mental health issues such as anxiety, depression, stress related problems, self-esteem issues, and compromised coping strategies. A physician's referral is required for admission to the program.

Appendix J

Debriefing Script

Thank you again for your participation in this study. There is one component of this study that I purposefully did not explain at the time of participation. For some kinds of psychological studies, it is necessary to wait until the completion of the study to fully explain the purpose as to ensure the final results are valid. Studies that examine how an individual reacts to a situation in everyday life sometimes require that the explanation of the purpose of the study be postponed until the end of the experiment. This ensures that individual will act naturally and will be less influenced by the experimenters and perceptions of their expectations.

It was explained that the purpose of this study was to examine cardiac responses to food preferences, namely chocolate taste tests. Although it is true that this study examined cardiac responses to delicious chocolate images, this study also looked at the effect of resisting or craving temptation to chocolate on subsequent chocolate consumption. In one group we asked participants to crave chocolate while viewing delicious chocolate images. In another group we asked participants to resist thoughts of chocolate while viewing the same images. In the last group participants were given no instructions while they viewed neutral images. Empirical research indicates that people who suppress thoughts of chocolate subsequently consume more compared to those that do not suppress their thoughts. The focus of this study was to examine this effect among University women. We were concerned that if we told you that we would be measuring the amount of chocolate candies that you consumed after viewing the images that you might have consequently changed the amount you consumed. Or, alternatively, that you would be inclined to pay more attention to the amount of candies you ate than you normally would in everyday circumstances.

Considering that we did not give you all of the information about this study up front, we would like to ensure that you are satisfied with your experience and participation and that you wish to keep your data in this study. If this new knowledge makes you uncomfortable with volunteering your data, we will remove it from our pool. To request that your data be removed from our pool, please contact the researcher at (807) 472-1607.

Thank you again for the time and effort that you put into this study. If you have any questions or concerns, please do not hesitate to ask.

Thanks,

Loretta Blanchette, B.A. (Hons.)
M.A. Clinical Psychology Candidate
Lakehead University, Thunder Bay, ON
lblanche@lakeheadu.ca
Phone: (807) 472-1607