Acute effects of exercise on self-regulation of snacking-related variables among habitual snackers

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

........................................ (Hwajung Oh)
ABSTRACT

Theories of health behaviour change largely focus on two process, one involving cognitions and one involving more automated and responsive behaviour (Rothman, Sheeran, & Wood, 2009). The former theories focus on beliefs and attitudes, planning, intentions and goal focused actions. The latter focus on capacity to self-control actions in certain situations. Self-regulation theory considers the effort that people invest to control their own responses to achieve particular goals (Vohs & Baumeister, 2004). Within theories of addiction, self-control is fundamentally challenged. Incentive-Sensitization theory (Robinson & Berridge, 1993) suggests that cues become associated with incentive value and a sensitised motivational response. Despite the best of intentions to avoid a certain unhealthy behaviour, a learned automatic response becomes the norm. Only recently have aspects of eating become linked to addictive behaviour (Avena, Rada, & Hoebel, 2008; Benton, 2010) and the idea of building self-regulatory capacity is of increasing interest (Johnson, Pratt & Wardle, 2011).

Short single bouts of exercise appear to reduce self-reported cravings, engagement in addictive behaviours, and salience of cues associated with the behaviour for smokers (Taylor, Ussher, & Faulkner, 2007), and rehabilitating alcoholics (Ussher, Sampuran, Doshi, West, & Drummond, 2004). Regular exercise may also have benefits on self-regulation of other behaviour (Oaten & Cheng, 2006; Ussher, Taylor & Faulkner, 2008). Studies of animals addicted to various substances also support the idea that physical activity attenuates consumption (e.g., Smith, Schmidt, Iordanou, & Mustroph, 2008).

The aims of this thesis were to examine the effect of a short bout of exercise on self-regulatory processes associated with snacking involving behavioural observation, self-report measures, direct and indirect measures of attentional bias. Also the effects of different intensities of exercise, level of stress, participant weight, smoking status, and period of abstinence were explored.

In Study 1, ad libitum chocolate consumption was measured in a simulated workplace (low and high stress situation via Stroop task). The effect of prior moderate intensity exercise (a 15 min brisk walk) was compared with a passive condition in a randomised 2 x 2 factorial design, involving 78 abstaining regular chocolate eaters. The main findings of Study 1 were that the two (low & high stress) exercise groups ate significantly less chocolate than the passive groups. The manipulation of different stress situations did not influence the effect of exercise on chocolate consumption.
Study 2 and Study 3 involved a randomised counterbalanced cross-over design in which the effects of exercise were compared with a passive condition. In Study 2, the effect of moderate intensity exercise (a 15 min brisk walk) on self-reported craving and attentional bias (using a visual dot probe task, with chocolate and neutral images presented in matched pairs) (both measured before and after each condition) were assessed among different groups (normal and overweight people, and 1 day and > 1 week (during Lent) chocolate abstainers) with a total of 58 participants. Exercise significantly reduced chocolate craving and attentional bias to chocolate images compared with a passive condition and the effects were similar irrespective of Body Mass Index and abstinence period.

In Study 3, given that abstinent smokers are at risk of emotional eating and weight gain, regular smokers and snackers were asked to abstain from smoking. Self-reported craving and attentional bias (using an eye tracking technology with short video clips) for both snack foods and cigarettes (presented alongside neutral images) were measured. The effects of two different intensities of exercise (i.e., 15 mins of moderate and vigorous intensity cycling) were examined among 23 temporarily abstinent smokers compared with a passive condition. The findings revealed that subjective snack cravings and strength of desire to smoke were reduced during and immediately after both moderate and vigorous exercise. In terms of attentional bias, initial attentional bias (% of first fixation) to snacking/smoking images were reduced after both intensities of exercise and maintained attentional biases (% of dwell time) to snacking/smoking images were reduced only after vigorous exercise.

Overall, the series of studies found that a short bout of moderate intensity exercise appears to reduce cravings and attentional bias to snack-related food cues, and the effects were similar among different groups, different type/intensity of exercise, and different measures of cravings. The findings of this thesis have therefore suggested that compared with being sedentary a short bout of physical activity may help to enhance self-regulation of snacking among people with a habit of snacking, particularly with chocolate.
Acknowledgements

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Study 1 was published as: Oh, H. & Taylor, A. H. (2012). Brisk walking reduces ad libitum snacking in regular chocolate eaters during a workplace simulation. Appetite. 58, 387-392.

Conference Abstracts


Chapter 1. Introduction

Some people encounter difficulties in regulating their impulses, desires, and behaviour in everyday life. This effort by individuals to alter their own responses is defined as ‘self-regulation’ (Vohs & Baumeister, 2004). Self-regulation is the important ability to control unplanned desires in the short-term and maintain goal-directed behaviour in the long-term. Thus, self-regulation as a controlled process is about overriding impulsive behaviour (Baumeister & Heatherton, 1996). Failure to self-regulate can be caused by various factors such as lack of control strength to override urges and impulses (Baumeister & Heatherton, 1996) and of particular importance, the inability to manage attention. Self-regulatory failure is associated with many social problems such as drug abuse and violent crime behaviours (Baumeister & Vohs, 2004), and a failure to control snacking even in the absence of hunger can contribute to weight gain, obesity, and diabetes (Herman & Polivy, 2004; Graaf, 2006). Indeed, Baumeister and Heatherton (1996) have argued that self-regulation can be improved, and cognitive treatments for a range of addictive behaviours involving attention re-training are being investigated (Schoenmakers, Wiers, Jones, Bruce, & Jansen, 2007; Field, Munafo, & Franken, 2009). This thesis explores the possible role of engaging in bouts of physical activity as a useful intervention for increasing self-regulatory capacity.

The National Health Service Information Centre (NHSIC, 2011) reported that the percentage of the adult population, who are obese, in the UK, has gradually increased from 13% in 1993 to 22% in 2009 for men and from 16% to 24% for women, with similar trends among young people. This can be attributed to both patterns of physical activity and dietary behaviour. The NHSIC also found that only 6% of males and 4% of females met the government’s recommended physical activity level of 30 minutes of moderate intensity physical activity five times a week, and 32% of men and 33% of women were sedentary for 6 or more hours on a typical weekday. Their dietary behaviours indicate they are still consuming foods with a high sugar content as they were 10 years ago.

From a clinical perspective, individuals with eating disorders show repeated self-regulation failure when snacking. According to a review by Benton (2010), binge eating often involves the consumption of a palatable food (e.g., cookies, chips), if large amounts are consumed it is possible to develop an addiction (e.g., sugar addiction) due to over-release of opioids. In terms of the general population, a USA Nationwide Food Consumption Survey (Piernas & Popkin, 2010), snacking behaviour significantly increased from 1977 to 2006. The amount of total energy consumed from snacking increased from 18 to 24%. Changes in the western world (e.g., sedentary lifestyle, the easy availability of food, widespread advertising) may have caused an
increase in snacking behaviours. Regular meals (i.e., breakfast, lunch and dinner) may be replaced by hedonic eating patterns (e.g., frequent consumption of highly palatable foods), which create a challenge for people to self-regulate. Snacking is often not driven by homeostatic hunger (i.e., eating when one is hungry), but by hedonic hunger (i.e., by the desire for highly palatable food with often high fat content) when no energy deficit exists (Lowe & Butryn, 2007).

With hedonic hunger, the intense desire to eat a certain type of food becomes a ‘food craving’ (Weingarten & Elston, 1990) linked to reward and mood regulation. A controversial issue is whether food craving can be regarded as a ‘food addiction’ like other drug addictions. To support the idea of food addiction, studies showed the neurobiological and behavioural commonality between sugar addiction and drug addiction (Avena et al., 2008; Benton, 2010). However, Benton (2010) pointed out in a review paper that highly palatable food is not addictive in itself, but it can become so with presentation and repeated consumption of the food. Rogers and Smit (2000) agreed that eating and drug use have certain commonalities, but hesitated to use the term of ‘food addiction’ as eating does not produce the powerful neuroadaptive effects, which are characteristic of drug addiction. Although the degree of food craving may generally be weaker than in drug addiction, food addiction has similar components of addiction (e.g., bingeing, withdrawal, craving, sensitization) (Avena et al., 2008).

It is well known that exercise is one of the beneficial strategies to control weight due to increasing energy expenditure. There is also considerable literature on the effects of exercise on energy intake, appetite, and hunger. Review papers (Hopkins et al., 2010; Martins et al., 2008a; Blundell et al., 2003) have shown that long-term (chronic) studies revealed various effects of exercise on energy intake: no changes, partial compensation, or decreases in energy intake. However, because of limitations in measuring energy balance (e.g., difficulties of measuring energy expenditure over the long-term), the majority of studies have focused on acute effects of exercise. Acute studies help to understand how chronic exercise could influence eating behaviour.

Similar to chronic studies, review papers showed that an acute bout of exercise can increase energy intake and appetite in some people and decrease or show no change in others (Hopkins et al., 2010; Martins et al., 2008a; Blundell & King, 1999; King, Tremblay, & Blundell, 1997b). There are several explanations to explain these conflicting results (Martins et al., 2008b; Blundell et al., 2003). For example, energy compensatory beliefs explain the increased energy intake following exercise (King, 1999) and changes in energy balance regulating hormones explain decreased energy intake following exercise (Ueda et al., 2009a; 2009b). One limitation with this research is that most studies have focused on the effect of long durations of exercise on
appetite or hunger with longer duration (King et al., 2010b) or high intensity of exercise (King et al., 2010b). There is also lack of research on how a single session of physical activity impacts on snacking behaviour. Most research is focussed upon the physiological influence of exercise. It would be beneficial to examine the effects of exercise on food craving (e.g., desire to eat, cue-reactivity) to understand self-regulation on snacking. Social Cognitive Theory (Bandura, 1989) provides support to this notion and highlights the need to consider individuals and their environment to predict behaviour. A vulnerable individual (e.g., with a desire to eat) and a vulnerable environment (e.g., food stimuli) would be greatly challenged to self-regulate eating behaviour.

The enhancing effect of exercise on self-regulation of craving has been shown in other addiction studies such as smoking (Taylor et al., 2007; Janse Van Rensburg et al., 2009a; 2009b) and alcohol (Ussher et al., 2004). A single session of moderate intensity exercise not only attenuated cigarette craving and attentional bias to smoking-related images (Janse Van Rensburg et al., 2009a) among temporarily abstained smokers, but also reduced withdrawal symptoms (Taylor et al., 2007). Considering that food craving can have addiction-like properties, it may be that there will be a similar effect of exercise on self-regulation of snacking. Only a few studies have examined the effect of exercise on food craving and hedonic eating (Thayer et al., 1993; Taylor & Oliver, 2009). Taylor and Oliver (2009) found that chocolate craving was lower after 15 min brisk walking than after the resting condition and Thayer and colleagues (1993) found that a 5 min brisk walk decreased an urge to snack. Further research is needed to investigate the role of exercise in reducing actual consumption of snack foods and in controlling attention toward snack food related stimuli, among regular snackers.

Baumeister and Heatherton (1996) stated that emotional stress can cause self-regulation failure for unhealthy behaviours such as smoking, drinking alcohol, and the consumption of high energy snack food (Macht & Simons, 2000; Oliver & Wardle, 1999). Given that exercise can have positive effects on mood and affective valance and activation (Reed & Buck, 2009; Ekkekakis et al., 2000; Taylor, 2010), it is possible that physical activity may enhance self-regulation of unhealthy behaviours, by attenuating stress and negative affect and increasing positive affect. In a smoking study, Taylor and colleagues (2006) found walking reduced cigarette cravings and tension and increased affective valence and activation among temporarily abstained smokers. The authors suggested a mediating role of affect (reduced emotional stress) in the effect of exercise on cigarette cravings. Taylor and Oliver (2009) also indicated that activation was increased from pre to post exercise and greater increases in activation were associated with greater decreases in chocolate cravings. Further studies are needed to examine the mediating effect of affect between exercise and self-regulation of snacking, and whether exercise can help to self-regulate emotional eating under stressful situations.
This thesis examines the effect of acute exercise on self-regulation of snacking and contains three studies. Study 1 (Chapter 3) focuses on self-regulation of snacking during manipulated stress situations. It investigated the effects of an acute bout of moderate intensity exercise on *ad libitum* chocolate consumption during the performance of computerised tasks (i.e., Stroop task) of low and high demand. Study 2 (Chapter 4) was designed to look at the control of attention and self-regulation of snacking using the visual dot probe task involving different groups. The study examined if moderate intensity exercise acutely reduces cravings and attentional bias to chocolate images and if the effects differ among normal and overweight people, and among regular chocolate eaters after short and long-term abstinence from chocolate. Study 3 (Chapter 5) focused on the effects of exercise (of different intensities) on snacking among abstinent smokers who had a tendency to snack. The study was designed to investigate if a single bout of moderate and vigorous intensity exercise would reduce cravings and attentional bias to snack food and cigarettes, using eye tracking technology and snack food and cigarette video clips.

The next chapter (Chapter 2) provides a critical review of literature relevant to the research described in this thesis such as definitions of food craving and addiction, measurement issues, and the effect of exercise with a proposed mechanism. Chapter 3 - 5 provide an introduction, methods, results, discussion, conclusion and directions for future research for each of the three studies. Chapter 6 provides an overview of all the findings and general discussion linked back to previous research and theories. Theoretical and applied implications of the research and potential limitations are discussed, and proposals for future research suggested. Lastly, an overall summary of findings and discussion is presented in Chapter 7.
Chapter 2. Literature Review

This chapter will provide a background for the concept and theories of food craving and the potential role of exercise in regulating energy intake. It includes the following sub-divisions: 1) food craving; 2) applied addiction theories; 3) other theories of relevance to health behaviours; 4) factors influencing food craving and food consumption; 5) measurement issues; 6) the effects of exercise on eating behaviours and related constructs

2.1. Food craving and addiction

2.1.1. Definition of addiction and craving

The term of “addiction” is used in many contexts to describe obsession and compulsive behaviours, and it implies psychological dependence. There are two main sets of criteria in common use to define addiction: the American Psychiatric Association’s DSM-IV-TR (APA, 2000, Table 2.1) and the World Health Organisation’s ICD-10 (WHO, 1992).

Table 2.1. DSM-IV-TR substance dependence criteria (APA, 2000)

<table>
<thead>
<tr>
<th>Criteria</th>
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<tr>
<td>(1) Substance taken in larger amount and for longer period than intended</td>
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<tr>
<td>(2) Persistent desire or repeated unsuccessful attempt to quit</td>
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<tr>
<td>(3) Much time/activity to obtain, use, recover</td>
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<tr>
<td>(4) Important social, occupational, or recreational activities given up or reduced</td>
</tr>
<tr>
<td>(5) Use continues despite knowledge of adverse consequences (e.g., failure to fulfil role obligation, use when physically hazardous)</td>
</tr>
<tr>
<td>(6) Tolerance (marked increase in amount; marked decrease in effect)</td>
</tr>
<tr>
<td>(7) Characteristic withdrawal symptoms; substance taken to relieve withdrawal</td>
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(Source from Gearhardt, Corbin, & Brownell, 2009)

While other addictions such as alcoholism and drug abuse are perhaps more easily understood, “food addiction” is a contemporary term used to describe a pathological disorder about food. Recently, foods have been considered as substances of abuse because they share common criteria and pathways of reward. Avena, Rada, & Hoebel (2008) compare drug dependence and food dependence, particularly sugar dependence, with reference to the four common aspects of the DSM-IV-TR dependence criteria: (1) Bingeing, which is the escalation of intake with a high
proportion of intake at one time, especially after abstinence or forced deprivation; (2) Withdrawal, which is manifested by the characteristic withdrawal symptoms; (3) Craving, which occurs when motivation is enhanced, usually after an abstinence period; (4) Sensitization, which is measured as increased reward seeking behaviours in response to repeated administrations of a substance. In this way, food addiction can be compared with other addictions, such as alcohol, tobacco, or gambling.

Craving, a problematic term for the addiction literature (Hill, 2007), is a subjective feeling of a strong urge to do something (West, 2006) and in the context of food it can be a hedonic response to food (Hill, 2007). Thus, food craving is defined as an intense desire to eat a certain food (Pelchat, 1997; Weingarten & Elston, 1990). Food craving has similar characteristics as other drug craving. From a physiological perspective, food craving is associated with activation of certain brain regions (e.g., hippocampus, insula and caudate) which are involved in drug-craving (Pelchat, Johnson, Chan, Valdez, & Ragland (2004). Just as other cravings (O’Connell, Schwartz, Gerkovich, Bott, & Shiffman, 2004) predict relapse, food craving may predict relapse or weight-gain in obese patients (Budak & Thomas, 2009).

One eating disorder, bulimia nervosa, is closely related to aspects of food craving, such as loss of control over the restriction of food intake, in particular. Bulimia nervosa is defined as recurrent binge eating accompanied by a feeling of lack of control over eating, followed by purging, and a persistent over-concern with body shape and weight (APA, 2000). It has a number of possible causes such as some emotional needs, certain social situations, and stressful events. Emotional eating (of relevance to this thesis), which refers to a tendency to eat more when anxious or emotionally aroused (Conner & Armitage, 2002), could be a causal factor of bulimia. However, bulimia is considered a clinical condition and pathological behavioural pattern, which requires a range of treatments including anti-depressants, behaviour therapy or cognitive-behaviour therapy (Conner & Armitage, 2002). Emotional eating is assumed to make individuals feel better, and using food as an escape from feeling negative emotions can reflect limited coping resources (Evers, Stok, & de Ridder, 2010; Radin, Hayssen, & Walsh, 2007; Thayer, 2001).

2.1.2. Homeostatic hunger vs. hedonic hunger

As a subjective experience, food craving may reflect some biological or physiological needs of the body. From the homeostatic point of view, energy intake is driven by biological needs and energy balance is determined by physiological satiety signalling systems (Schwartz, Woods, Porte, Seeley, & Baskin, 2000). Schwartz et al. (2000), in their review paper, explained energy homeostasis as a network of neuropeptides and biogenic aminergic neurotransmitters such as
insulin and leptin, which links peripheral and central components. The models for energy homeostasis help us to understand how individual hormonal and neuropeptide signalling pathways control food intake. However, our eating behaviour is controlled by highly complex processes which go beyond survival through the maintenance system of energy homeostasis and the avoidance of starvation. Specifically, we need to consider hedonic hunger. Hill, Weaver, and Blundell (1991) state that food deprivation was not a necessary condition for food craving, and the factors driving craving may be more likely to be psychological reasons such as mood. For example, similar to the withdrawal symptom of gamblers or drug-dependents, people experience frequent thoughts, feelings and urges about food even when there is no energy deficit. Lowe and Butryn (2007) contrast homeostatic hunger, which results from prolonged absence of energy intake, to hedonic hunger, which is strongly influenced by the availability (i.e., food related-cues) and palatability of food in the environment. These distinctions help to explain why some foods are still desired and consumed although there is no energy deficit (i.e., desiring a dessert after a filling meal).

Some evidence suggests the independence of these two systems. Yeomans and Gray’s (2002) review paper suggests that an opioid antagonist reduces the rated pleasantness of palatable foods but has no effect on the rated hunger between antagonist and placebo conditions. De Graaf, De Jong, and Lambers (1999) found that pleasantness of foods has an effect on satiation but not on subsequent satiety. This implies that hedonic systems can occur free from biological need. An early pharmacological study (Blundell & Hill, 1987) provides evidence for the independent processes of the two systems through the finding that the administration of the serotonin drug D-fenfluramine suppressed the sensation of hunger, but had no effect on the pleasantness of food. Erlanson-Albertsson (2005) explains how hedonic food has an influence on homeostatic appetite regulation (see Figure 2.1). Appetite regulation is a complex interaction of hunger and satiety signals in the brain, especially in the hypothalamus. As Figure 2.1 shows, both feedback systems are related to similar processes. However, consumption of palatable food, which is related to hedonic hunger, induces an increased activity of reward mediators (i.e., Dopamine, Opiates, and Serotonin), and with resistance to satiety signals, the drive to eating is continued. Thus, hedonic food offsets normal appetite regulation and leads to overeating, which may explain the difficulty of weight management. However, the motivation to eat is a response to more than a single need. Although there would appear to be a distinction between homeostatic hunger and hedonic hunger, it is difficult to find a clear distinction between them.
2.1.3. Liking vs. Wanting

Hedonic eating motives can be driven by an interaction of ‘liking’ (i.e., the taste of food) and ‘wanting’ (i.e., the incentive salience of food stimuli) or experiencing one (either ‘liking’ or ‘wanting’) without the other (Lowe & Butryn, 2007). ‘Liking’ is a hedonic reaction to the pleasure of a reward (e.g., pleasure derived from oro-sensory stimulation of food), whereas ‘wanting’ is modulated by sensory and/or cognitive influences (e.g., incentive salience, the motivation to engage in eating) (Berridge, 2009; Mela, 2006). Mela (2006) explained the connection between these two concepts in that ‘liking’ is an essential component of ‘wanting’ and ‘wanting’ is a major contributor to ‘liking’.

The Determinants of Food Choice Model (Mela, 2006) helps explain these complicated processes of eating behaviours. The idea of this model is that the desire to eat a particular food is caused by the influences of internal state (i.e., psychophysiology), liking (i.e., pleasure), and external stimuli (i.e., learned cues, cognitive or unconscious components) (see Figure 2.2), and any situation can induce more or less stimulation of desire to eat (Mela, 2006). This model implies that the complicated process of food intake and the desire to eat is caused by various causal factors, and could result from single or multiple factors.
The distinction between affective and motivational processes has been investigated to understand human digestive behaviour. As a measurement issue, ‘liking’ is commonly assessed by using taste reactivity patterns, which measure subjective ratings of palatability, and ‘wanting’ is measured by investigating specific food cravings with food stimulus for reward seeking behaviours (Finlayson, King, & Blundell, 2007b). For example, Finlayson, King, and Blundell (2007a) measured ‘liking’ through pleasantness ratings and ‘wanting’ through a forced-choice photographic procedure, for photographic food stimuli (high/low fat and savoury/sweet foods). Sixty participants visited a laboratory at lunch time without consuming any food for at least 3hrs and the ‘liking’ and ‘wanting’ task were completed pre (in a hungry state) and post meal (in a satiated state). They found that they ‘wanted’ high-fat savoury food and ‘liked’ high-fat sweet foods in the hungry state, but they ‘wanted’ low-fat sweets and ‘liked’ high-fat savoury in the satiated state. Although there was a limitation that food images were used for the task and actual foods were not tasted, this study provided evidence for them being conceptually unique. Similarly, in another study (Epstein, Truesdale, Wojcik, Paluch, & Raynor, 2003), seventeen females were randomised to fed (a 20min meal) or food deprived (a 20min reading magazine) condition. The subjective rating for hedonics (i.e., taste reactivity to pleasant, unpleasant, and neutral tastes) was measured before and after meal session, and the reinforcing value (i.e., a snack food) was assessed after the meal session. In the deprived condition participants were more motivated towards a response for food (i.e., more reinforcing) than in the fed condition, but the subjective rating for pleasure was not influenced by conditions (fed or deprived). They concluded that hedonics and reinforcing value of food can be distinguished.

In short, ‘liking’ and ‘wanting’ are compatible and the systems while independent can also happen together. As suggested by Mela (2006), eating behaviour is a complicated process and
the process may be affected by various factors such as environmental factors and individual differences. Figure 2.3 shows what the differences in psychological features is and how ‘liking’ and ‘wanting’ have been measured. This distinction helps us to understand why we suddenly think of eating when we smell cooking when passing a shop.

![Diagram of liking, wanting, and learning inside reward](Source from Berridge, 2009)

### 2.2. Applied addiction theories

Some eating behaviour can be linked to addictive behaviour and addiction theories may offer an insight into the mechanisms underpinning food craving. Several theories will be discussed including ‘cognitive’ and ‘psycho-physiological’ perspectives.

#### 2.2.1. Cognitive theories

Cognitive theories of addiction explain motivation-induced addictive behaviour and help to understand and explain how repeated behaviours occur. Five theories (i.e., Hedonic Theory, Self-regulation Theory, Reinforcement theories of addiction, Incentive-Sensitization Theory, and the PRIME Theory) will be introduced in this section.
2.2.1. Hedonic Theory

It is not clear when the concept ‘Hedonic Theory’ began to be used in addiction studies. While its earlier use was in marketing, Hedonic Theory is currently used to explain how people’s affective response is related to addictive behaviours and eating behaviour. The principle of this theory is that people are motivated to approach (enhance) pleasure and avoid (or minimize) pain and it is related to self-regulation in terms of the tendency of promotion and prevention (Higgins, 1997). Hedonic Theory explains behaviours as an affective consequences or anticipation of affective consequences. Williams (2008) stated that the perceived positive affective response and experience will determine subsequent repeated events. One of the theories related to addiction, the Opponent Process Theory (Solomon, 1980), supports this view, and notes that addicts consciously decide to continue to use a drug to avoid withdrawal symptoms and maintain hedonic balance (West, 2006) and eventually this leads to failure of self-regulation during abstinence.

Some other expectancy theories, such as Response Expectancy Theory (Kirsch, 1997) and Expected Pleasure Theory (Mellers, Schwartz & Ritov, 1999), could give further support to understand the principle of Hedonic Theory: They consider previous affective experience as an important factor. In drug addiction, the basic idea of Expectancy Theories is that the level of drug consumption (i.e., alcohol, nicotine) is related to how much the person expects the drug to deliver a desired affect (West, 2006). For example, heavier drinkers report more positive expectancies about drinking alcohol than lighter drinkers (Southwick et al., 1981). Response Expectancy Theory (Kirsch, 1997) and Expected Pleasure Theory (Mellers et al., 1999) hypothesise that behaviours are determined by the expectation of affective response to the behaviour and its associated outcomes, and emphasise the importance of expected pleasure in determining behaviour. Kirsch (1997), in his review paper, stressed the important role of response expectancies on problematic behaviours and the effects of placebos.

As mentioned in the earlier section (hedonic hunger, liking, and wanting), Hedonic Theory has been applied in health behaviour research such as food craving (Finlayson et al., 2007b; Mela, 2006; Urala & Lahteenmaki, 2006) and smoking (Dawkins, Acaster, & Powell, 2007). They are commonly based on Hedonic Theory, which is about the tendency of experiencing pleasure.

2.2.1.2. Self-regulation Theory

Self regulation, a term sometimes used interchangeably with self-control, generally refers to any effort by a human being to alter its own responses (i.e., regulating their thoughts, emotions, appetites, or task performances) (Vohs & Baumeister, 2004). Self-regulation involves the self
acting on itself to alter its own responses and regulation of an individual’s responses is usually initiated with the goal of achieving a desired outcome such as improving one’s mood or avoiding an unwanted outcome (Schmeichel & Baumeister, 2004). Schmeichel and Baumeister (2004) describe that self-regulatory strength is the internal resources available to inhibit or alter responses that may occur as a result of physiological processes, habit, learning, or the pressure of the situation. Self regulation is complex process and it can fail in several ways. Baumeister and Heatherton (1996) stated that self-regulation can fail by an inability to set appropriate standards and monitoring action, and by a lack of strength to control responses. They also suggested that strength can differ by an individual’s capacity, emotion (stress or fatigue depletes), and the control of attention. They stressed that managing attention is important to success in self-regulation and loss of attentional control will be a common predictor of self-regulatory failure.

The failure of self-regulation features in theories of addiction and additive behaviours are often related to affect regulation. For example, Hull and Slone (2004) reviewed the relationship between alcohol consumption and affect regulation. They noted that alcohol consumption was related to the avoidance of negative affect and enhancement of positive experiences. In another alcohol study, Hussong, Hicks, Levy, and Curran (2001) examined whether alcohol use was related to affect among 74 college students by completing repeated assessments of mood, alcohol use, friendship quality, and social support. They found that students with less intimate and supportive friendships showed risk for greater drinking following relative increases in sadness and hostility.

This self-regulation framework can be applied to eating behaviour as part of an affect regulation process. As drug and alcohol are used as a method of controlling the users’ social, emotional, or other psychological difficulties, self-regulation of eating also could be used as a way of coping with problems that are being faced. For instance, Tice, Bratslavsky, & Baumeister (2001) investigated the relationship between affect regulation and eating behaviour under induced sad and distressed mood. Seventy-four students were randomly assigned to one of four conditions: distressed or happy condition (i.e., manipulated by reading a real-life scenario and imaging the situation), and mood-induction (i.e., no instruction) or a mood-freeze condition (i.e., manipulated by instructions that specified that eating would not produce a change in mood). A taste test (i.e., three kinds of foods: pretzels, chocolate chip cookies, and small cheese crackers) following 15 minutes of reading and imaging was presented and participants were left in the room alone for 10 minutes. Just before leaving participants alone, the mood-freezing manipulation was introduced. The results show that people in the frozen sad mood condition ate less than people in a sad but changeable mood. Their results are possibly interpreted by the idea
that people under emotional distress eat more unhealthy foods because they expect that the palatable food will make them feel better.

Seen from this point of view of self-regulation of affect, eating behaviours are used as a mediator for the balancing of affective state. People regulate their eating on the basis of internal physiological signals or cognitive calculations of appropriate foods (or amounts of foods) to eat (Herman & Polivy, 2004). Self-regulation of eating is influenced by other factors such as social factors (e.g., eating in group), emotional factors (e.g., emotional stress), and diet condition (e.g., dieter, restrained eater) (Herman & Polivy, 2004). For example, restrained eaters (dieters) showed strong automatic approach tendencies (Veenstra & de Jong, 2010) and become more likely to overeat when they are exposure to attractive food cues (i.e., palatable food) (Fedoroff, Polivy, & Herman, 2003).

Self-regulation Theory has tremendous explanatory potential for different forms of addiction and food craving. Understanding of self-regulation and its success/failure on eating may offer an explanation about the phenomenon of a sense of urge, craving, and impulsiveness. Self-regulation may be able to improve by repeated practice over time. For instance, Oaten and Cheng (2006) tested whether regulatory behaviour can be improved via a 2 month self-regulation programme (i.e., involving a programme of regular physical activity). They found that there were significant improvements in a wide range of regulatory behaviour (e.g., decreases in smoking, alcohol, and caffeine consumption, and increases in healthy eating and emotional control) over a 2 month programme.

2.2.1.3. Reinforcement Theories of Addiction

Similar to the principle of Hedonic Theory, reinforcement theories of addiction are related to approach and avoidance learning mechanisms. Engagement in behaviours that may become addictive involves a learning mechanism, and that may predict the development of subconscious behaviour. The learning mechanism is associated with Classical conditioning and Instrumental conditioning. Classical conditioning, also known as ‘Pavlovian conditioning’, indicates that drug craving is caused by repeated environmental stimuli (Stimulus → Response) and stresses the association between the conditioned stimulus (CS) and unconditioned stimulus (US) (West, 2006; Hogarth & Duka, 2006). On the other hand, Instrumental conditioning suggests that addictive behaviours arise from one’s response followed by reinforcement (reward behaviour) (Response → Stimulus) and stresses the relationship between response and stimulus (West, 2006).
As a stimulus, a reinforcer increases the frequency of an addictive behaviour and a strong reinforcer can motivate the behaviour that it follows (Epstein, Leddy, Temple, & Faith, 2007). Reinforcement, which is a fundamental determinant of choice (motivation) and follows as a consequence of the behaviours (Epstein, Salvy, Carr, Dearing, & Bickel, 2010), is a two-sided process. One is positive reinforcement and the other is negative reinforcement. *Positive reinforcement* suggests that an addictive behaviour is induced by a reward or positive reinforcer with repetition of a ‘cue-response-reward’ association (West, 2006). This generally means that the positive reinforcers become stimuli that have the property of increasing the probability of behaviours; thus addicts are motivated to take drugs for pleasure (Robinson & Berridge, 2000). While positive reinforcement theories involve seeking rewarding stimuli, *negative reinforcement* is related to escaping/avoiding an unpleasant stimulus (Lewis, 1990). In other words, addicts continue addictive behaviour as a means of avoiding aversive states.

Hogarth and Duka (2006) explained this emotional conditioning (positive and negative reinforcement) based on the principle of the Classic Incentive Theories, in which a stimulus causes addictive behaviour without cognition (e.g., out of self-control). They explained that a stimulus elicits an appetitive emotional state and that emotional conditioned response motivates instrumental drug-seeking behaviour (positive reinforcement). Also, a stimulus elicits an aversive emotional state and that aversive emotional conditioned response motivates instrumental drug-seeking behaviour (negative reinforcement). In a book chapter, Hull and Slone (2004) described the relationship between alcohol consumption and affect regulation, and the function of alcohol as a mean of reducing negative states (affect regulation). From reviewing previous studies, they summarised that alcohol is consumed in part as a means of avoiding negative affective states and enhancing positive affective states.

As reinforcement theories of addiction provide an insight into maintenance of addictive behaviours, reinforcement theories may also explain how people crave for certain foods (i.e., palatable and comfort food) and how it is related to a recalled sense of pleasure after eating. Reinforcement theories, as part of a learning mechanism, offer an explanation for addictive behaviours and how they can happen with limited conscious choice or awareness. However, this is not entirely sufficient to explain how behaviour is associated with stimuli/cues (the sight, smells of food), or impulsiveness that can cause increases of immediate subjective craving.

2.2.1.4. Incentive-Sensitization Theory

Although reinforcement Theory may explain how someone becomes addicted to certain substances and develops a motivation to continue the addictive activity, behaviour is more complex. For example, the behaviour can result from grabbed attention to particular cues, rather
than Instrumental and Classical conditioning. Robinson and Berridge (2003) point out that S-R habit may explain addicts’ implicit learning processes, but they note, in addition to habit learning, that the commonly observed flexible and compulsive drug-seeking behaviour needs an additional motivational explanation (See Figure 2.4). The stimulus-response habit learning model (see left on Figure 2.4) indicates that addiction is mainly due to the development of strong stimulus-response habits [thick arrow from a conditioned stimulus (CS) to a response (pursuit)] (Robinson & Berridge, 2003). On the other hand, the Incentive Sensitisation Theory (see right on Figure 2.4) suggests that the initial change is in the ability of representations of drug cues to engage in a sensitised motivational response of incentive salience which leads to compulsive drug seeking behaviour [see thick arrow via an unconditioned stimulus (US)].

![Figure 2.4. Two models of addictive behaviours](image)

The stimulus-response (S-R) habit learning model (left) and the incentive sensitisation Theory (right). (Source from Robinson & Berridge, 2003).

The Incentive Sensitisation Theory of addiction proposes that drug-related stimuli or cues produce a bias in attentional processing and a psychological process involved in motivated behaviour (compulsive ‘wanting’) (Robinson & Berridge, 1993, 2008). In other words, repeated exposure to potentially addictive drugs could change neural networks in the brain that regulate the attribution of incentive salience to stimuli (Robinson & Berridge, 2008). Excessive incentive salience by cues is attributed to ‘wanting’, and the incentive salience can be separated from hedonic effects of substances (‘liking’) (West, 2006). Thus, drug-related cues which are salient stimuli trigger drug taking and drug seeking behaviours.

Bias occurs when we believe things we want to believe. Attentional bias is a form of cognitive bias where certain behaviours become the normal response in specific situations (West, 2006). Robinson and Berridge (1993) suggested that salience attribution alters the sensory features of the incentive stimulus into an especially salient perception (i.e., ‘grabs attention’) which
becomes attractive and wanted. This biased attention guides behaviour to the incentive and it becomes attractive as a conditioned incentive. Based on Robinson and Berridge’s model (1993; 2003), many experimental studies have examined attentional bias for drug-related cues among addicts with different measurements (i.e., the Stroop colour word task, the dot probe task, eye-tracking system). For example, Waters and Feyerabend (2000), and Bruce and Jones (2004) reported that problem drinkers and smokers showed a selective interference effect for words related to their addictive behaviour (e.g., cigarette or beer) in the Stroop colour naming task. Also, Waters, Shiffman, Bradley, and Mogg (2003) found that heavy smokers showed faster responding to a visual probe that replaced a smoking picture than a neutral picture. In addition, there is some evidence for a relationship between attentional bias and food cues (Hollitt, Kemps, Tiggemann, Smeets, & Mills, 2010; Kemps & Tiggemann, 2009; Newman, O'Connor, & Conner, 2008). Kemps and Tiggemann (2009) examined attentional bias to chocolate-related stimuli in chocolate cravers and non-cravers by using a dot probe task with pictures (i.e., chocolate, food and transport). The result showed that only self-reported chocolate cravers had an attentional bias toward chocolate-related pictures.

This theory supports the compulsive drug-seeking/taking behaviour which is not often motivated directly by the desire for a hedonic effect or to relieve withdrawal. Furthermore, Robinson and Berridge’s (1993, 2001, 2008) comment about a dissociation between the incentive salience attribution (wanting) and subjective pleasure (liking) allows an explanation of an addiction (become wanted) to a certain thing (e.g., drug, tobacco, food), when its pleasure-rating decreases. However, the incentive salience may not lead to an addictive behaviour by itself, and when it is combined with other factors such as feeling states or social factors the desire will be stronger.

2.2.1.5. The Elaborated Intrusion (EI) Theory of desire

Our desire for certain things (e.g., food, drug) could be driven by unexpected initial thought, the imagery of that target object or behaviour, and an affective response (e.g., pleasure) from the imagery. Kavanagh, Andrade, and May (2005) introduced The EI Theory by distinguishing two processes: one process is triggered by intrusive thought about the target and the other process is associated with cognitive elaboration which is related to affect (see Figure 2.5). They explained that intrusive thoughts about a certain target can rise from various types (e.g., verbal or image) and can happened while subjects’ attention is focused on another task. Elaboration refers to the act of searching for information which is related to the target and remembers the information in working memory as a result of highly elaborated cognition (Kavanagh et al., 2005).
Figure 2.5. The Elaborated Intrusion (EI) Theory of desire
(Source from Kavanagh, Andrade, and May, 2005)

In Figure 2.5, the central box involves a subjective conscious experience of desire. The oval external boxes on the top and bottom of the central box are external factors and antecedents drawn from past experience (i.e., external cues, anticipatory responses to the target such as salivation, other cognitive activity, negative affect, and physiological deficit states). The rectangle boxes in the central box are the products of elaborative processing. Thin and thick arrows give an indication of possible processes. Thin arrows, automatic components of desire, lead to spontaneous thoughts (intrusive) and thick arrows include all cognitive processes (retrieval of semantic, episodic, and sensory information from long-term memory) and the use of that information to create images of the desired target. Later, Kavanagh, May, and Andrade (2009) tested the EI theory of desire to alcohol disorders and found that during alcohol craving imagery was experienced by 81% and the frequency of imagery was associated with stronger craving.

This theory describes automatic and associative processes supporting intrusive desire-related thoughts and the processes of elaboration, and also explains how various variables have an influence on desire. Incentive-Sensitization Theory (Robinson & Berridge, 1993) focused on the function of a salient target in motivation, whereas this theory especially emphasised the importance of sensory images. Also, EI theory explains how weak thoughts of substance use, or in other words weak cravings, become stronger with further imagery to a point where behaviour may be difficult to self-regulate.
2.2.1.6. PRIME Theory

PRIME Theory (West, 2006) provides a framework for conscious and unconscious motivational processes. The theory developed as a synthesis of motivational processes from conscious decision-making through to classical and instrumental learning processes. PRIME Theory consists of five motivational systems: 1) P = plans (conscious mental representations of future actions plus commitment); 2) R = responses (starting, stopping or modifying actions); 3) I = impulses/inhibitory forces (can be consciously experienced as urges); 4) M = motives (can be consciously experienced as desires); 5) E = evaluations (evaluative beliefs) (West, 2006) (see Figure 2.6).

![Figure 2.6. The human motivational system (Source from ‘www.primmetheory.com’ by West)](image)

The components influence each other inside and outside of the motivational system with the ever-changing network of an external and internal environment. Behaviour starts from reflex responses, though impulses, motives and evaluations and the processes allow greater flexibility to consider a wider range of factors (West, 2006). Contrary to other motivation theories, PRIME Theory stresses the flow of behaviour on a moment to moment basis (West, 2006), which is not always predictable. Although an intention to do something may exist, at any moment a plan can change due to impulses. PRIME Theory explains the gap between intention and action with reference to various possible factors. For further discussion on impulsivity and substance use see page 56.

2.2.2. Psycho-physiology

Cognitive addiction theories explain the relationship between environmental cues and subjective craving, the complicated cognitive process with motivational systems, and the fact that engagement in an addictive behaviour often occurs in the absence of cravings. However, both
cognitive and psycho-physiological processes of addictive behaviours are useful. Psycho-
physiological pathways of addiction offer an additional explanation of how people become
addicted and why addicts crave in the presence of salient stimuli.

There are several frameworks to investigate neuropsychology and cognitive functioning when
people are addicted to certain substances. Volkow, Fowler, and Wang (2003) proposed four
interactive neural networks which include brain circuits of reward (saliency: red circle\(^{(1)}\)),
motivation/drive (internal state: green circle\(^{(2)}\)), memory and learning (learned associations:
gold circle\(^{(3)}\)), and control (conflict resolution: blue circle) (see Figure 2.7\(^{(4)}\)).

![Neural Networks Diagram](image)

A) the non-addicted brain; B) the addicted brain

**Figure 2.7.** Volkow et al (2003)’s four neural networks model
(Source from Volkow, Wang, Fowler, Tomasi, Telang, & Baler, 2010)

For addicted people (see B in Figure 2.7), the enhanced value of drug and drug-related cues in
the reward, motivation/drive, and learning/memory paths overwhelms the inhibitory control
exerted by the prefrontal cortex, and that give rise to compulsive drug intake (Volkow et al.,
2003). On the other hand, for non-addictive people (see A in Figure 2.7), the three paths operate
in a balanced interaction with inhibitory control. Although this model offers some basic
concepts of relevance to addictive behaviour and treatment strategies to overcome addiction, it
may be not enough to explain more complicated aspects of the behaviour and may need to
include other factors such as mood. Volkow, Wang, Fowler, and Telang (2008) extended this
model to the neurobiological regulation of feeding and the four neural networks occur with
repeated exposure to highly palatable food, which is similar to repeated drug exposures.
Similar to the four neural networks addiction model in food craving, Rolls (2007) introduced a conceptual diagram to show how the sensory factors interact in the brain with satiety signals and how these things lead to appetite and eating (see Figure 2.8). While brain mechanisms control appetite, a wide range of sensory and environmental factors that make food increasingly palatable overstimulate the sensory system and override satiety signals (Rolls, 2007). This model links neuroscience with a psychological perspective by considering several factors which are related to the brain’s food reward systems such as satiety signals, sensory factors (e.g., visual stimulation), and cognitive factors. However, this model has also disregarded subconscious behaviour (i.e., emotional eating, impulses) and unexpected cravings from moment to moment (see Figure 2.6 PRIME Theory above and following emotional state and cravings section).

![Figure 2.8. Schematic diagram of brain processing (Source from Rolls, 2007)](image)

Rewarding effects are clearly one of the key factors to trigger addictive behaviour and neural systems. In particular the mesolimbic (dopaminergic/opioid) system plays an important role in mediating the rewarding effects of drugs and other incentives (Robinson & Berridge, 2000). West (2006) noted that the various theories related to dopamine propose that the action of dopamine on receptors in the nucleus accumbens (NAcc) plays a key role. Tomkins and Sellers (2001) explain that addictive substances (i.e., drugs and alcohol) exert rewarding effects by the mesolimbic dopamine pathway, causing an increase in dopamine levels within the NAcc, and drugs of abuse influence dopamine concentrations in the NAcc in several different ways (see Figure 2.9). This is an important model to explain the effects of cues on drug-seeking behaviour. The theory may also be supported by food related studies. Many imaging studies have reported an increased activation in the mesolimbic system when an individual is exposed to a highly palatable food cue (Roll & McCabe, 2007; Goldstone, Prechtl de Hernandez, Beaver,
Muhammed, Croese, & Bell et al., 2009). However it is difficult to explain these mechanisms clearly.

A)

![Brain Diagram](image)

B)

![Diagram of mesolimbic dopamine pathway](image)

**Figure 2.9.** The brain area of the mesolimbic dopamine pathway (A) and the process of the activity of the pathway (B) (Source from Tomkins & Seller, 2001)
Neurotransmitters in the brain may help to understand how certain brain areas are activated and how food craving occurs. Many of the neurotransmitters such as Dopamine and Opioids are implicated in food cravings and those are related to brain regions involved in reinforcement (Avena et al., 2008; Pandit, de Jong, Vanderschuren, & Adan, 2011). For example, in parallel to our understanding of the mesolimbic dopaminergic system in other drug research (Tomkins & Sellers, 2001), a variety of foods, such as sugar, can lead to the release of Dopamine in the nucleus accumbens shell (Rada, Avena, & Hoebel, 2005). Mesolimbic dopamine has an important role in reward systems and this reward from food and other drugs share similar substrates for motivational processes (Pelchat, 2002). In addition, Serotonin, which has many roles such as influencing sleep, appetite, impulse control and mood elevation (Parker, Parker, & Brotchie, 2006), may have an influence on food craving (Pelchat, 2002; Rogers & Smit, 2000). Parker and colleagues (2006), in a review, suggested that chocolate or carbohydrate craving correlated with a serotonin deficiency, particularly in depressed individuals who attempt ‘self-medication’ as carbohydrate consumption may lift serotonin level and mood.

2.3. Factors influencing food craving, interest (attentional bias), and food consumption

Factors such as gender, Body Mass Index (BMI), environmental cues, and cognitive factors can influence food craving and consumption, and these will be discussed in this section under headings: 1) personal characteristics (i.e., gender, age, BMI); 2) dieting condition; 3) cue exposure; 4) emotional state; 5) personality (i.e., impulsivity); 6) other health-risk behaviours. A review of this literature will be used to inform the design of studies conducted within this thesis.

2.3.1. Gender, age, BMI and cravings

Only a few studies have examined the effects of gender on food craving and mainly report differences in the types of craved foods between males and females. Lafay, Thomas, Mennen, Charles, Eschwege, and Borys et al. (2001) found (using self-report questionnaire) that 28% of women and 13% of men were reported as food cravers among participants and 20% of female cravers and 50% of male cravers reported that subjectively it was easy for them to resist a desire to eat. In terms of food preference, males preferred meals with food such as steak, casseroles, and soup, while females preferred snack foods such as chocolate and ice cream (Wansink, Cheney, & Chan., 2003). Wansink and colleagues (2003) also found that younger people liked snack foods more than those over 55 years of age. Pelchat (1997) used structured interviews to examine the differences in types of food craved, by gender and age. He found that women
reported significantly more cravings for chocolate and sweets than did men, and cravings declined with age. Contrary to the previous finding that women preferred snack foods, from the International Health Behaviour Survey (IHBS), with a total of 19,298 university students from 23 different countries, Wardle and colleagues (2004) found that women were more likely to avoid high-fat foods and to eat fruit and fiber than men, and they were likely to be dieting to lose weight.

BMI is also one of the factors which may have an influence on food cravings. Some studies have found a positive relationship between BMI and food craving (Nijs, Muris, Euser, & Franken, 2010; Ferriday & Brunstrom, 2010; Castellanos, Charboneau, Dietrich, Park, Bradley, & Mogg et al., 2009; Soetens & Braet, 2007). Ferriday and Brunstrom (2010) found that after cue exposure (sight & smell of a food) an overweight group (n=52) showed greater response and greater motivation to consume food than a normal weight group (n=52). In an attentional bias study (Nijs et al., 2010), 40 normal weight and 26 overweight/obese females were randomly assigned to a hunger or satiety condition, and their response to food was measured using an eye-tracking system, a visual dot probe task, and a recording of electro-physiological brain activity (EEG) during a counting task. They did not find group differences on attentional bias from eye-tracking and on EEG data, but with the dot probe task overweight/obese females showed greater initial attentional bias (i.e., 100ms stimulus) to food images compared with normal weight females, especially while hungry. Similar to Nijs and colleagues’ study, eighteen obese and eighteen normal weight women were exposure to food and non-food images in a fasting or satiety condition, and attentional biases were assessed by using an eye-tracking system and a visual dot probe task (Castellanos et al., 2009). They did not find any differences between the normal weight and the obese group using the visual dot probe task. However, there were group differences in gaze direction and gaze duration bias in the satiety condition, but not in the fasted condition. In other words, overweight group had greater attentional biases to food cues in the satiety condition than the normal weight group. Furthermore, in a study with adolescents (Soetens & Braet, 2007), overweight adolescents recalled more food words than control words compared with normal weight adolescents. Neuroscience evidence gives further support to the previous studies about the differences between normal weight and overweight people. In a review paper, Volkow, Wang, and Baler (2011) report the different responses to food cues between obese and normal weight people. They summarised that obese subjects showed increased activation of reward related brain regions (e.g, NAc, ACC, amygdale, hippocampus) when they were exposed to high-calorie food images in an fMRI scanner compared with normal weight people.
2.3.2. Dieting condition and cravings

Dieting is an intentional and sustained restriction of caloric intake for the purpose of weight control (Stice, Fisher, & Lowe, 2004; Herman & Mack, 1975). Restrained eating is related to self-regulation in eating behaviour (e.g., as an indicator for overeating tendencies) (see a review paper by Johnson, Pratt, & Wardle, 2011).

The effects of dietary restraint and disinhibition on eating behaviour have been frequently investigated. An association between dietary restraint and food craving was found in short-term manipulation in the laboratory (Polivy, Coleman, & Herman, 2005). They found that chocolate-deprived (for 1 week) participants ate more chocolate in a taste test situation (compared with non-deprived participants), and restrained eaters experienced more food cravings than did unrestrained eaters. Veenstra and de Jong (2010) compared the cravings for high/low-fat foods between restrained eaters and unrestrained eaters. They found that unrestrained eaters craved more for low-fat than high-fat food, whereas restrained eaters did not show differences in self-reported craving between high-fat and low-fat food.

In one attentional bias study (Holliitt, Kemps, Tiggemann, Smeets, & Mills, 2010) similar results were reported with restrained eaters responding faster to detect a food word (compared with a neutral word) than unrestrained eaters. On the other hand, some research did not find this expected relationship between restrained eating and food craving. Ahern and colleagues (2010) reported that there were no differences between high and low restrained eaters on attentional bias and approach tendencies toward food cues, but both groups showed attentional bias and approach tendency to appetizing food (high calorie food) images. Giesen and colleagues (2009) examined the differences between 36 unrestrained non-dieters, 20 restrained non-dieters, and 15 current dieters on a points collecting task for snack food. In the computer based task, participants were instructed to press a responding key to one of the food options (snack food or fruit/vegetable) and told that they would have to eat the earned food at the end of the task. They found that subjects who were currently dieting worked less hard to obtain snack food, whereas those who were not currently dieting and were higher restrained eaters worked harder to get snack food.

Previous evidence, overall, showed that dieting states and restrained eating are associated with an increase in food cravings and attentional bias to food cues. However, food craving is a more complex process and several influencing factors occur together. For example, when restrained eaters are dieting or when they experience negative mood, their eating behaviours will be different from the one expected.
2.3.3. Cue exposure and cravings

The effects of cue exposure have been explored extensively in drug-taking behaviours, such as presenting cigarettes related objects (Field & Duka, 2004) and holding and smelling an alcoholic drink (Jansma, Breteler, Schippers, De Jong, & van der Staak, 2000). Similar reactivity to food-related cues has also been observed in food studies (Kemps & Tiggemann, 2009; Brignell, Griffiths, Bradley, & Mogg, 2009; Tuomisto, Hetherington, Morris, Tuomisto, Turjanmaa, & Lappalainen, 1999; Fedoroff, Polivy, & Herman, 1997). Kemps and Tiggemann (2009) did two studies using chocolate-related pictures and real chocolate bars. In study 1, 40 chocolate cravers and 40 non-chocolate cravers were exposed to chocolate pictures and non-chocolate related food pictures via a visual dot probe task. They found that chocolate cravers had higher attentional bias to a chocolate picture compared to non-chocolate cravers. In their other study, 106 females who liked chocolate were randomly assigned to one of two conditions: a chocolate elicited craving (by choosing a favourite chocolate bar from a basket, unwrapping it, and placing it on a small tray underneath the computer monitor) or a control condition (by choosing a favourite coloured wood block from a basket and placing it on a small tray underneath the computer monitor). After exposure to cues, they were asked to do the same dot probe task with chocolate pictures. Chocolate cravings were assessed using a 100-mm visual analogue scale at 3 time points: on arrival at the laboratory (baseline), immediately before the dot probe task, and at the end of the dot probe task. They found that participants who were in a chocolate craving condition had higher attentional bias to chocolate-related pictures than those in a control condition. A chocolate craving group also showed significantly higher self-reported chocolate cravings at immediately before and after the dot probe task compared with a control group.

Fedoroff, Polivy, and Herman (2003) used more sensitive cues rather than using pictures. Sixty restrained and seventy-two unrestrained females were exposed to smelling (from an oven which was out of sight of the participant) one of three cues (pizza, cookies, or no cues) for 10mins and were asked to write their thoughts about the cue. They were then presented with either pizza or cookies to taste and rate. Restrained participants ate (in grams) more when the food presented to eat was the same as the smelled food cue and there was no effect of specific cues for unrestrained eaters. Self-reported desire to eat and craving (measured by a 100mm-VAS) increased after exposure to smelling a food cue for restrained eaters. Wang and colleagues (2004) also showed the effects of food-related cues by measuring psychophysiological reactions (using a PET scanner). They reported that food deprived (between 14 and 16 hours) participants showed significantly increased metabolism in the whole brain, especially in the superior temporal, anterior insula, and orbitofrontal cortices. Also, activation in the right orbitofrontal cortex was significantly correlated with the increases in the self-reported desire for food.
Although there are enough findings to support that cues increase cravings and grab one’s attention (Incentive-Sensitisation Theory), it is not clear whether cue-induced cravings can predict actual addictive behaviours. Perkins (2009) argued that the evidence is not clear to explain the relationship between cue-reactivity (cue-induced craving) and actual maintained addictive behaviour (e.g., relapse). In a review he highlighted that craving is influenced by abstinence from a substance (abstinence-induced craving) and presentation of the substance related cues (cue-induced craving). However, abstinence-induced craving seems to predict relapse risk, cue-induced craving does not appear to. He also stressed the weakness of the link between self-report measures of cue-induced craving and relapse risk. Contrary to Perkins’s (2009) arguments, Shiffman (2009) stated that most relapse episodes (initial lapses) occur during cue exposure and cue-provoked craving. Waters and colleagues (2004) also found nicotine replacement therapy (NRT) reduced overall cravings (withdrawal based) but not cue-induced craving, and cue-induced craving predicted relapse among subjects who were on NRT. Overall, cue-induced craving may explain one’s relapse behaviour, however more evidence is needed to explain the relationship between them.

2.3.4. Emotional state and cravings

Review papers (Macht, 2008; Gibson, 2006; Canetti, Bachar, & Berry, 2002) show that emotional state can change eating behaviour. Emotion is conceptually distinct from mood. Emotion is a short-term affective response to particular stimuli and situations; in contrast, mood persists longer and is more diffuse (Gibson, 2006).

Emotion-induced eating has been explained by psychological (Geliebter & Aversa, 2003; Lowe & Fisher, 1983), physiological (Willner, Benton, Brown, Cheeta, Davies, & Morgan et al., 1998; see a review by Gibson, 2006), and biological mechanisms (see a review by Rogers & Smit, 2000). Macht and Simons (2000) examined the relation between emotional states (experienced in everyday life) and motivation to eat, on 6 consecutive days among 23 females. They found that the self-report motivations to eat were mostly higher during negative emotional states (i.e., “Anger-dominance” and “Tension/Fear” cluster). In these states the participants tended to eat to provide distraction, to relax, and to feel better. In a similar study, Macht (1999) showed that while angry, participants experienced higher levels of hunger and impulsive eating. In terms of food preference, during stress, more high caloric foods, such as snack-type food, and less meal-type foods, such as vegetables and meat, were consumed (Oliver & Wardle, 1999).

Stress is one of the most common factors having an influence on emotional changes. Stress is generally defined as an aversive state and the result of an individual’s perception that the demands of the environment are excessive relative to one’s capabilities (Conner & Armitage,
Stress may have acute or chronic effects on physiological, psychological and behavioural changes that impact on eating behaviours and researchers have tried to explain these effects. Adam and Epel (2007) proposed a theoretical model of reward based stress eating, which highlights the psycho-neuroendocrine basis of stress-related eating (see Figure 2.10).

Figure 2.10. Theoretical model of reward based stress eating (Source from Adam & Epel, 2007)

According to this model, stress can cause greater cortisol exposure and can directly or indirectly affect reward pathways leading to excessive intake of high caloric foods (e.g., cookies, chocolates). The combination of these processes can contribute to increased visceral fat, which is related to obesity. Epel and colleagues (2004) also found that the physiological changes (e.g., higher insulin and cortisol level) and the increases in weight during psychological stress periods (i.e., exams) were greater than the baseline (non-exam period).

Greeno and Wing (1994) proposed a more complex model, the Individual-Difference Model (see Figure 2.11). This model predicts that different levels of vulnerability (i.e., obese vs. non-obese, restrained vs. non-restrained eaters) will cause different eating behaviour when an individual is experiencing stress. In terms of considering psychological or environmental mechanisms, this model allows wider explanations of the relationship between stress and eating behaviour.

In previous studies, the relationship between stress and eating behaviours has been widely investigated in different situations (e.g., experimental condition, natural setting), with different types of stressors, and types of consumer (e.g., restrained eaters). For example, in experimental studies, stress has been induced by mood manipulations (e.g., videos of unpleasant accidents) (Yeoman & Coughlan, 2009), cognitive tasks (e.g., counting backward by seven, Stroop colour-word task) (Wallis & Hetherington, 2009; Taylor & Oliver, 2009) and by physical stressors
(e.g., partial immersion in very cold water, noise) (Lattimore & Maxwell, 2004). Naturalistic stress such as examination and working stress has been assessed in epidemiological surveys (Sims, Gordon, Garcia, Clark, Monye, & Callender et al., 2008; Oliver & Wardle, 1999) and in-situ experiential sampling studies (Weidner, Kohlmann, Dotzauer, & Burns, 1996).

**Figure 2.11.** Stress-induced eating models: The Individual-Difference Model
(Source from Greeno & Wing, 1994)

Table 2.2 and Table 2.3 show summaries of studies which have assessed the effect of naturalistic stress and laboratory based-stress on eating behaviours, respectively.

The Table 2.2 and 2.3 firstly built on previous reviews (Greeno & Wing, 1994; Torres & Nowson, 2007). Greeno and Wing (1994) reported 3 human studies of chronic stress and 13 human studies of acute stress. Torres and Nowson (2007) reported 8 human studies of chronic stress and 6 human studies of acute stress. More information about participant’s information, study design and measurements used was added to their review tables and further recent studies added by searching for studies in Medline and Pubmed with searching terms (stress OR food intake OR snacking OR stress-induced eating OR acute stress OR life stress) to do a qualitative review. The aim was to accumulate a wide range of literature on the link between stress and eating-related variables to inform the design of the first study in this thesis. It was not to conduct systematic quantitative review.
Table 2.2. The effects of chronic stress on eating-related variables

<table>
<thead>
<tr>
<th>Author</th>
<th>Participants (N, gender, age etc)</th>
<th>Study design</th>
<th>Measures used</th>
<th>Stressor</th>
<th>Food types</th>
<th>Effects on food cravings or eating behaviours (any moderators)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willenbring et al., 1986</td>
<td>N=80 (20 M, 60 F), age 42.0yrs</td>
<td>Cross sectional study</td>
<td>Symptom Checklist-90 (SCL-90), a questionnaire concerning their eating habits, food preference on a scale</td>
<td>Recall by questionnaire</td>
<td></td>
<td>Preference for high caloric foods is predicted by being a stress eater and a lower level of current stress.</td>
</tr>
<tr>
<td>Van Strien et al., 1986b</td>
<td>N= 1208 (589 M, 619 W)</td>
<td>Longitudinal study</td>
<td>DEBQ, a Dutch Life Events Questionnaire, The scale for emotional eating</td>
<td>Negative life events</td>
<td></td>
<td>Short-term effect (6months); a significant interaction effect of emotional eating and negative life events on change in BMI. Long-term effects (18months); for men, emotional eating and negative life events were found to have a significant interaction effect on change in BMI, but not for women.</td>
</tr>
<tr>
<td>Lingswiler &amp; Crowther, 1987</td>
<td>N=56 F</td>
<td>Longitudinal study (2weeks)</td>
<td>Multiple Affect Adjective Checklist (MAACL), The Daily Food Schedule, The Binge Scale</td>
<td>Life stress during 2 weeks</td>
<td></td>
<td>For binge eaters, negative mood states were experienced during a significantly greater proportion of binge episodes than non-binge episodes.</td>
</tr>
<tr>
<td>Popper &amp; Meiselman, 1989</td>
<td>N=475, age 45.6±10.3yrs</td>
<td>Cross sectional study</td>
<td>Eating in Combat questionnaire (records how much food eaten on the first 3 days of the 1st and 2nd combat experiences)</td>
<td>Combat experiences.</td>
<td></td>
<td>Participants reported that they ate less than usual during combat, especially their first combat experience (ranging from 68% on the first day of the first combat situation, to 45% on the third day of the second combat situation).</td>
</tr>
<tr>
<td>Bellisle et al., 1990</td>
<td>N=12 males</td>
<td>Longitudinal study</td>
<td>Palatability, anxiety, and hunger on 100 mm VAS</td>
<td>Before the surgery for hernia</td>
<td></td>
<td>There was no difference in food selection between stress day and control day.</td>
</tr>
<tr>
<td>Study</td>
<td>Sample Characteristics</td>
<td>Study Design</td>
<td>Measures</td>
<td>Workload</td>
<td>Findings</td>
<td></td>
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<tr>
<td>McCann et al., 1990</td>
<td>N=14 (3 M, 11 F) Cross sectional study</td>
<td>Four-day food records, subjective estimates of stress and workload (a scale from 0 to 100), blood samples</td>
<td>Workload (high-workload: before major work deadlines, low-workload: during a quiescent period of work)</td>
<td>-</td>
<td>During high workload, dietary intake of calories, total fat, saturated fat, and the percentage of calories from fat were significantly higher than low workload.</td>
<td></td>
</tr>
<tr>
<td>Spillman, 1990</td>
<td>N=500 (250 M, 250 F) Cross sectional study</td>
<td>Self-reported questionnaires (i.e., whether stress was important, what the stressful situations were, and what methods were used to alleviate stress)</td>
<td>Life stress</td>
<td>-</td>
<td>Comforting foods (mostly carbohydrates) consumed during periods of stress. Women ate candy/sweets more often than men.</td>
<td></td>
</tr>
<tr>
<td>Michaud et al., 1990</td>
<td>N=225 high school students (78 boys, 147 girls), age 16.6±0.1yrs Longitudinal study (1 week)</td>
<td>A one-day food record</td>
<td>Examination stress</td>
<td>-</td>
<td>Total energy intake and amount of fat were significantly increased on the stressful event day, especially for girls.</td>
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<tr>
<td>Stone &amp; Brownell, 1994</td>
<td>N=158, age 43.2±10.1yrs Longitudinal study Daily records of stress and eating for 84 days</td>
<td>A daily questionnaire booklet</td>
<td>Life stress</td>
<td>-</td>
<td>Individuals were much more likely to eat less in response to stressful daily problems. Males had a tendency to eat less than females, and females in the highest level of stress were three times less likely to eat compared to the other levels of stress.</td>
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<tr>
<td>Pollard et al., 1995</td>
<td>N=179 (n=115 in the exam-stress; F age21.7±2.9yrs, BMI 23.8±3.8 kg/m²; M age22.8±3.3yrs, BMI 24.4±3.0; N=64 in the control group: F Longitudinal study Tested twice (2 to 3 months before the exam time-baseline session, and then within 2 weeks of the start of exam week)</td>
<td>DEBQ, STAI, Perceived stress scale(PSS), General Health Questionnaire (GHQ), Social Support Questionnaire (SSQ), State Anxiety Scale, FCQ, Dietary assessment, Blood sample for blood lipids</td>
<td>Academic examination</td>
<td>-</td>
<td>The exam-stress group reported significant increases in perceived stress and deterioration in emotional well-being at the exam sessions compared with baseline sessions. The exam-stress group with high trait anxiety and low social support showed a significant increase in total energy intake and the amount of fat between baseline and exam sessions, whereas individuals with low trait anxiety</td>
<td></td>
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<tr>
<td>Study</td>
<td>Sample Size/N</td>
<td>Design</td>
<td>Measures</td>
<td>Stress Period</td>
<td>Findings</td>
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<tr>
<td>Weidner et al., 1996</td>
<td>N=133 (36 M, 97 F), age 21±4yrs</td>
<td>Longitudinal study</td>
<td>PANAS-X, the Wellness Inventory of the lifestyle Assessment Questionnaire</td>
<td>Low stress period: the second week of the semester</td>
<td>High stress period: two days before final exams week; and high social support showed a reduction in energy intake.</td>
<td></td>
</tr>
<tr>
<td>Weinstein et al., 1997</td>
<td>N=101 (49 M, 52 F)</td>
<td>Cross sectional study</td>
<td>STAI, the Eating Inventory, RS, the Eating Attitudes Test, Binge Scales</td>
<td>Life stress (recall)</td>
<td>For females, during the stressful situation, higher scores on disinhibition were highly correlated with eating more than usual for females, but not for males.</td>
<td></td>
</tr>
<tr>
<td>Steptoe &amp; Lipsey, 1998</td>
<td>N=44</td>
<td>Longitudinal study (8weeks)</td>
<td>STAI, the social support questionnaire, FCQ, the perceived Stress Scale, the Hospital Anxiety and Depression (HAD) scale, the Hassles and Uplifts Scale, POMS, weekly diary packs</td>
<td>Life stress during (during 8 weeks, selected the 2 weeks with highest perceived stress scores and the two weeks with the lowest perceived stress scores)</td>
<td>Fast food was eaten more frequently during high stress weeks than low stress periods. Mood influenced the choice of food. Greater consumption of sweet foods and cheese.</td>
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</tr>
<tr>
<td>Oliver &amp; Wardle, 1999</td>
<td>N=212 (63 M, 149 F)</td>
<td>Cross sectional study</td>
<td>Self-reported weight concern on a 5-point scale, stress-induced eating questionnaire</td>
<td>Life stress (recall)</td>
<td>Under stress, more likely to eat snacks (73%) regardless of gender &amp; dieting status, less likely to eat meal-type foods. Dieters were significantly more likely to report hyperphagia when stressed (58%) than non-dieters.</td>
<td></td>
</tr>
<tr>
<td>Macht &amp; Simons, 2000</td>
<td>N=23 F (age 23±2yrs, BMI 20.4±1.8 kg/m²)</td>
<td>Between subject 6 consecutive days</td>
<td>Eating-Behaviour and Weight-Problem Inventory, TFEQ, motivation to eat (10items)</td>
<td>Emotion and eating related items on a 7-point scale (anger, fear, sadness, joy, tension, relaxation)</td>
<td>During the presence of negative emotions (anger-dominance, tension/fear), motivations to eat to provide distraction, to relax, and to feel better were rated higher than during relaxation/joy or the unemotional state.</td>
<td></td>
</tr>
<tr>
<td>Wardle et al., 2000</td>
<td>N=90 (58 F-age 36.3±11.98yrs, BMI 23.9±3.6 kg/m², 32 M-age 34.7±10.1yrs)</td>
<td>Cross sectional study (over a 6 month period: measurement sessions = over 4 time periods)</td>
<td>A 24-hour food recall, interview, the Perceived Stress Scale, the General Health Questionnaire (GHQ), Working stress (high-work stress: average 47 hours, low-work stress: average 32 hours)</td>
<td>High-workload periods were associated with higher energy, saturated fat, and sugar intake. RE had higher energy intake and saturated fat intake in the high-work-stress session than low-work-stress session.</td>
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<tr>
<td>Study</td>
<td>Participants</td>
<td>Design</td>
<td>Measures</td>
<td>Findings</td>
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<tr>
<td>Cartwright et al., 2003</td>
<td>N=4,320 school children (2,578 M, 1,742 F), age 11.8±0.3yrs</td>
<td>Cross sectional study</td>
<td>The Perceived Stress Scale (PSS), food frequency questionnaires for fatty food, fruit and vegetable, snacking, and breakfast intake</td>
<td>Self-reported questionnaires</td>
<td>A higher perceived stress was associated with more fatty food intake, less fruit and vegetable intake, unhealthy levels of snacking and a reduced likelihood of daily breakfast consumption.</td>
<td></td>
</tr>
<tr>
<td>Ng &amp; Jeffery, 2003</td>
<td>N=12,110 (5,490 M, 6,620 F), age 40yrs</td>
<td>Cross sectional study</td>
<td>4-item Perceived Stress Scale, the Block Fat Screener, the Godin Leisure-Time Exercise Questionnaire</td>
<td>Life stress</td>
<td>Higher perceived stress was associated with a higher fat diet and lower levels of physical activity.</td>
<td></td>
</tr>
<tr>
<td>Epel et al., 2004</td>
<td>N=131 students, age 23.75yrs</td>
<td>Longitudinal study (two exam periods over 1year)</td>
<td>Physiological data (weight, waist-to-hip ratio, insulin, cortisol), self-reported questionnaire for stress-eating tendencies</td>
<td>Academic examination (2 exam periods over 1year)</td>
<td>Stress eaters showed increases in BMI &amp; nocturnal cortisol.</td>
<td></td>
</tr>
<tr>
<td>Macht et al., 2005</td>
<td>N=42 (22 exam group, 20 control group-no examination), age 24±3yrs, BMI 22±2.9 kg/m²</td>
<td>Longitudinal study, between-subjects design</td>
<td>Ten times daily: emotional and eating-related items on 7-point scales, TFEQ</td>
<td>Examination stress: tested 3-4 weeks before examination (baseline) and then 3-4 days before examination (stress period)</td>
<td>Students awaiting an exam reported higher emotional stress and greater tendency to eat than control group in order to distract from stress.</td>
<td></td>
</tr>
<tr>
<td>Sims et al., 2008</td>
<td>N=159 (76 M, 83 F), age 45.8±11.5, BMI 31.0±8.95 kg/m²</td>
<td>Cross sectional study</td>
<td>The Perceived Stress Scale (PSS-10), the Eating Behaviors Pattern Questionnaire (EBPQ)</td>
<td>Life stress (recall)</td>
<td>Perceived stress was associated with unhealthy eating behaviours (emotional eating and haphazard planning), but didn’t predict other eating behaviours (low fat eating, cultural/lifestyle eating, snacking on sweets and meal skipping).</td>
<td></td>
</tr>
</tbody>
</table>

Note. M – males; F – females; NW – normal weight; DEBQ – the Dutch Eating Behavior Questionnaire; PANAS - the Positive and Negative Affect Scales; TFEQ – The Three Factor Eating Questionnaire; POMS – Profile of Mood States; RS - the Restraint Scale; STAI – the State-Trait Anxiety Inventory Scale; VAS - Visual Analogue Scales; MAACL - the Multiple Affect Adjective Check List; RE – restrained eaters / NRE – unrestrained eaters
<table>
<thead>
<tr>
<th>Author</th>
<th>Participants (N, gender, age etc)</th>
<th>Study design</th>
<th>Measures used</th>
<th>Stressor</th>
<th>Food Types</th>
<th>Effects on food cravings or eating behaviours (any moderators)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schachter et al., 1968</td>
<td>N=91 (43 obese - mean age 20.5yrs, BMI 27.3 kg/m², 48 NW - age 19.9yrs, BMI 22.3 kg/m²)</td>
<td>Between-subjects randomly assigned to one of the four conditions (high vs. low fear, empty vs. full preloading)</td>
<td>5-point rating scales designed to measure degree of fear</td>
<td>Electric stimulation (low/high)</td>
<td>Five bowls of crackers</td>
<td>NW subjects ate more when they were calm and hungry than when frightened and full. However, obese subjects tended to eat more when they had high fear and were full.</td>
</tr>
<tr>
<td>Abramson &amp; Wunderlich, 1972</td>
<td>N=66 M (33 obese - age 20.4yrs, BMI 29.1 kg/m², 33 NW - age 20.1yrs, BMI 22.5 kg/m²)</td>
<td>Between-subjects randomly assigned to one of three conditions (control, interpersonal anxiety, or objective fear treatments)</td>
<td>The Multiple Affect Adjective Check List (MAACL), a digit span test (DS), the Cornell Medical Index Health Questionnaire</td>
<td>1) control: just eating 2) Interpersonal anxiety treatment: Interpersonal Stability Questionnaire with interpretation 3) Objective fear treatment: electric shock</td>
<td>Crackers</td>
<td>Obese males in the fear treatment condition tend to eat more crackers but there was insignificant differences in cracker consumption</td>
</tr>
<tr>
<td>Herman &amp; Polivy, 1975</td>
<td>N=42 F students</td>
<td>Between-subjects randomly assigned to high anxiety or low anxiety conditions</td>
<td>Mood scale, RS</td>
<td>The different levels of electrical stimulation for high and low anxiety</td>
<td>Ice-cream</td>
<td>Restrained subjects in high anxiety condition ate more ice-cream than those in low anxiety. However, unrestrained subjects showed the opposite patterns.</td>
</tr>
<tr>
<td>Reznick &amp; Balch, 1977</td>
<td>N=64 NW and obese subjects (18 M, 46 F)</td>
<td>A 2x2x2 Between-subjects randomly assigned to one of eight conditions (Subjects; obese/normal-weight, anxiety level; H/L, response cost; H(wrapped) / L. (unwrapped chocolate))</td>
<td>Self-Evaluation Questionnaire</td>
<td>High anxiety: intelligence test &amp; informed that a painful electric shock would be administered for every incorrect response Low anxiety: not related to intelligence level (easy task)</td>
<td>Chocolate (half wrapped &amp; half unwrapped)</td>
<td>Obese subjects in the low-response cost (unwrapped chocolate) and low-anxiety conditions tended to eat more than those in high-response cost and high-anxiety conditions. No differences in NW.</td>
</tr>
<tr>
<td>Frost et al., 1982</td>
<td>N=68 F undergraduates</td>
<td>Between-subjects randomly assigned to one of three groups (depressed, neutral or elated)</td>
<td>The Personal Feeling Scale (PFS), Multiple Affect Adjective Check List (MAACL-D), RS</td>
<td>Read a series of 50 self-referent statements (negative or positive mood)</td>
<td>Chocolates</td>
<td>High-restraint subjects in the depression condition ate significantly more chocolates than the other groups.</td>
</tr>
<tr>
<td>Year</td>
<td>Authors</td>
<td>Sample Size</td>
<td>Design</td>
<td>Measures</td>
<td>Task</td>
<td>Results</td>
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<tr>
<td>Ruderman, 1983</td>
<td>N=83 (41 obese, 42 NW)</td>
<td>Between-subjects randomly assigned to anxiety conditions (high vs. low), or relaxation condition</td>
<td>Subjunctive Units of Disturbance Scale (SUDS), STAI, Heart rate</td>
<td>Three tapes describing the high anxiety, low anxiety, and relaxation situation</td>
<td>Ice cream</td>
<td>Anxiety did not significantly influence the amount eaten among NW people. However, obese individuals consumed less ice cream when highly anxious than calm.</td>
</tr>
<tr>
<td>Ruderman, 1985</td>
<td>N=105 NW females</td>
<td>Between-subjects randomly assigned to one of two conditions (dysphoric mood or non-dysphoric mood condition)</td>
<td>RS, MAACL, concept formation task, the taste test</td>
<td>Non-dysphoric condition (success condition): given veridic feedback, dysphoric condition (failure condition): given predetermined bogus feedback</td>
<td>Crackers</td>
<td>High RE consumed more when in a dysphoric mood (failure condition) than in a non-dysphoric mood (success condition). Among two subscales of the RS, the correlation between concerns with dieting scores and grams eaten was significant in the dysphoric mood condition.</td>
</tr>
<tr>
<td>Pine, 1985</td>
<td>N=160</td>
<td>Between-subjects randomly assigned to one of two conditions: low anxiety (LA) or high anxiety (HA)</td>
<td>STAIS, a taste test</td>
<td>Presenting instructions about electrical stimulation test (high anxiety condition: told that it would be painful, low anxiety condition: told that the shock would definitely not be painful and barely noticeable), but no electric shocks delivered</td>
<td>Two brands of peanuts</td>
<td>Obese subjects consumed greater amounts of peanuts than did the non-obese subjects. Obese subjects in the HA consumed greater amounts of peanuts than did those in the LA.</td>
</tr>
<tr>
<td>Herman et al., 1987</td>
<td>N=80 F (RE &amp; URE)</td>
<td>Between-subjects randomly assigned to one of four conditions (high vs. low anxiety x deprived vs. preloaded conditions)</td>
<td>The State Anxiety Inventory, taste-rating questionnaire, the Eating Habits Questionnaire (RS)</td>
<td>Videotaping while performing jingle (Low anxiety: think about the aspects of the products participants had completed taste rating that should be highlighted in an advertising campaign High anxiety: told that they would be given time to compose an advertising jingle with presenting a video camera</td>
<td>Ice-cream</td>
<td>Deprived (hungry) dieters ate more when anxious than when calm (t_{17}=216, p &lt; .05), by contrast, deprived non-dieters ate slightly less when anxious than when calm. In the preloaded condition the amount eaten was increased by dieters and was decreased by non-dieters.</td>
</tr>
<tr>
<td>Cattanach et al, 1988</td>
<td>N=30 (15 eating disordered, 15)</td>
<td>Between-subjects randomly assigned to</td>
<td>Blood pressure, pulse rate, POMS,</td>
<td>The four experimental stressors for 3min</td>
<td>-</td>
<td>High-disordered eaters reported an increased desire to binge</td>
</tr>
</tbody>
</table>
controls)  

<table>
<thead>
<tr>
<th>Study</th>
<th>N=60, age 29.6±9.9yrs, BMI 23.9±0.9 kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schotte et al., 1990</td>
<td>Between-subjects randomly assigned to one of four conditions (restrained/unrestrained eater, negative affect/neutral affect) RS, POMS, Visual Analogue Mood Scales</td>
</tr>
<tr>
<td></td>
<td>20-min frightening film or neutral film Pre-weighted 400g of popcorn Negative affect triggered overeating (high restraint subjects exposed to the frightening film ate more than those exposed to a neutral film, t_{29}=7.13, p &lt; .001).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study</th>
<th>N=75 F (35 RE, 40 URE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heatherton et al., 1991a</td>
<td>Between-subjects randomly assigned to one of four conditions (shock treat, failure, speech treat, control condition) STAI, the Multiple Affect Adjective Check List, a taste task Shock treat (electrical shock), failure (symbol differentiation task), and speech treat (2-min speech) Three large bowls of ice-cream with different flavour.</td>
</tr>
<tr>
<td></td>
<td>RE in the speech threat &amp; failure condition ate more ice cream than control group. URE in the shock treat group ate significantly less ice-cream than control group.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study</th>
<th>N=91 F, age 28.6±8.9yrs, BMI 23.8±4.5 kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cools et al., 1992</td>
<td>Between-subjects randomly assigned to one of three film conditions RS, POMS, Visual Analogue Mood Scales (VAMS)</td>
</tr>
<tr>
<td></td>
<td>20 min-Films (Neutral, positive, and negative affect) A pre-weighed (400g) bag of buttered and salted popcorn</td>
</tr>
<tr>
<td></td>
<td>High RE viewed neutral film decreased food intake and those viewed both affect films increased food intake</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study</th>
<th>N=54 (26 M, 28 F), age 24.1±6.9yrs,</th>
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<tbody>
<tr>
<td>Grunberg &amp; Straub, 1992</td>
<td>Between-subjects randomly assigned to stress or control Self-report questionnaires assessing food Film: stress condition (industrial accidents), control condition (pleasant Pre-weighed snack food (sweet, salty, Stress decreased food consumption in men but increased in women. Women in</td>
</tr>
<tr>
<td>Study</td>
<td>Participants</td>
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<tr>
<td>Steer &amp; Cooper, 1993</td>
<td>N=48 F</td>
</tr>
<tr>
<td>Macht, 1996</td>
<td>N=56 M NW(age 23±2.5yrs, BMI 21.2±1.5 kg/m²)</td>
</tr>
<tr>
<td>Levine &amp; Marcus, 1997</td>
<td>N=40 (20 each with/without bulimic symptomatology) (BUL group: age 18.6±1.2yrs, BMI 22.6±2.1 kg/m²; CON group: age 18.4±0.8yrs, BMI 22.2±2.3 kg/m²)</td>
</tr>
<tr>
<td>Polivy &amp; Herman, 1999</td>
<td>N=137 F</td>
</tr>
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</table>

Note: The table contains data from various studies comparing experimental conditions and their effects on participants. The studies involve subjects assigned to different conditions and measured outcomes such as stress levels, eating behaviors, and psychological states. The table highlights the use of various materials and conditions to study eating preferences and behaviors.
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample size</th>
<th>Design</th>
<th>Measures</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willner et al., 1998</td>
<td>N=120 F (age 22.5yrs)</td>
<td>Between-subjects randomly assigned to two groups (elated condition or depressed condition)</td>
<td>The Attitudes to Chocolate Questionnaire, The IVE questionnaire, mood scales (on a 100mm- VAS)</td>
<td>Listening music intended to induce either elated or depressed moods</td>
</tr>
<tr>
<td>Rutledge &amp; Linden, 1998</td>
<td>N=77 F (age 20.3±3.4yrs)</td>
<td>Between-subjects</td>
<td>Blood pressure, Heart rate, PANAS, RS, TFEQ, self-report affect</td>
<td>Three cognitive task for 12mins (mental arithmetic, Stroop task, and Word Scramble Task)</td>
</tr>
<tr>
<td>Oliver et al., 2000</td>
<td>N=68 (27M, 41F) age 26.1±5.7yrs, BMI 22.1±2.4 kg/m²</td>
<td>Between-subjects randomly assigned to one of two conditions (stress or control)</td>
<td>PANAS, Copal digital sphygmomanometer UA-251 to measure physiological arousal, ratings of hunger &amp; appetite on a 7-point Likert scale, food intake during the meal, DEBQ, STAI</td>
<td>The treat of public speaking: anticipation of a speech performance (preparing a 4minute speech) immediately after meal time</td>
</tr>
<tr>
<td>Tanofsky-Kraff et al., 2000</td>
<td>N=82 F (age 18.5±0.9yrs, BMI 21.7±2.1 kg/m²)</td>
<td>Between-subjects randomly assigned to one of four conditions (puzzle failure, anticipatory speech, interpersonal manipulation , and control group)</td>
<td>The Sensation Questionnaire, ice cream taste test, RS</td>
<td>Puzzle failure, anticipatory speech, interpersonal manipulation</td>
</tr>
<tr>
<td>Epel et al.</td>
<td>N=59 F (age 36)</td>
<td>Between-subjects</td>
<td>POMS, the Eating</td>
<td>Three stress sessions: 1)</td>
</tr>
<tr>
<td>Year</td>
<td>Sample Description</td>
<td>Methodology</td>
<td>Findings</td>
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<tr>
<td>2001</td>
<td>4 consecutive days of sessions (the first 3 sessions = stressful session, the 4th = a rest or control session). Only the data from the 1st stress session and the control session were used.</td>
<td>Attitude Test, salivary cortisol, Trier Social Stress Test visuospatial puzzles, 2) serial subtraction of a prime number from a high number, 3) deliverance of a videotaped speech A rest session: see quietly, reading and listening to music</td>
<td>snacks (four types) stress day were significantly related to high cortisol level after stress. High reactors ate more sweet foods across days. Increases in negative mood during stress session were related to greater food consumption.</td>
<td></td>
</tr>
<tr>
<td>Lattimore, 2001</td>
<td>N=20 F (age 24±5.5yrs, BMI 22±1.6 kg/m²) Within-subjects STAI, the Bulimia test (BULLIT-R), a hunger-rating scale</td>
<td>A fearful film, The ego-threat Stroop task</td>
<td>Ice cream Stroop task produced greater ice cream consumption than the film task. Binge eaters consumed significantly more ice cream than non-binge eater.</td>
<td></td>
</tr>
<tr>
<td>Macht et al, 2002</td>
<td>N=48 M (age 28±6.55yrs, BMI 23.2±2.4 kg/m²) abstained from eating 2hrs (n=24) and 8hrs (n=24) A 4×2 factorial design randomly assigned to deprivation condition with within-subject factors (four emotion conditions: anger, fear, sadness, and joy) and between-subjects factor (food deprivation: 2 or 8hrs)</td>
<td>TFEQ, self-ratings of emotions on a 7-point scale Four emotion-inducing film clips</td>
<td>Chocolates Self-rated motivation to eat was higher after 8hrs food deprivation than 2hrs. Sadness decreased and joy increased appetite (a higher tendency to eat more chocolate and pleasant feeling about chocolate taste, in joy condition).</td>
<td></td>
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<tr>
<td>Haynes et al., 2003</td>
<td>N=80 F categorised to 4 groups (H/L-R, H/L-D)</td>
<td>Between-subjects randomly assigned to the stress or no stress condition (20 participants in each of the four R-D (high/low), 10 women from each group in the stress or no stress condition)</td>
<td>TFEQ-restraint (R) &amp; disinhibition (D), POMS, mood &amp; appetite scales The Concept Formation task (no stress condition-correct feedback, stress condition-false feedback). Also participants in the stress condition performed a Mental Arithmetic task before or after the CF task</td>
<td>Eight different food items (5 savoury items and 3 sweet items) In stress condition, both HR-HD &amp; LR-LD groups consumed more food than the no-stress condition, whereas LR-HD group ate less in the stress condition and HR-LD showed no response to stress. HD (LR-HD, HR-HD) group consumed significantly more sweet foods in both conditions.</td>
</tr>
<tr>
<td>Jansen et al., 2003</td>
<td>N=32 (Overweight children: n=16, age 9.6±1.2yrs, BMI 23.3±3.7 kg/m²; NW: n=16, age)</td>
<td>Within-subjects Attend 3 times in a taste test (preload, exposure, and control condition) with 1 week gap between conditions</td>
<td>Self-perception profile for children, Eating disorder examination, 9-point appetite, hunger, and mood scales, taste test Emotional cartoon faces (sad, happy, neutral) Buffet-style meal (7 large dishes: sweet, salty and bland snack foods)</td>
<td>NW children in preload &amp; exposure condition ate less than control condition. However, overweight children did not reduce food intake after eating a preload, and they tended to eat more after the intense smelling</td>
</tr>
<tr>
<td>Study</td>
<td>Sample Size</td>
<td>Design</td>
<td>Conditions</td>
<td>Measures</td>
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<tr>
<td>Bekker et al., 2004</td>
<td>N=52 F</td>
<td>Between-subjects</td>
<td>A 2×2 factorial design: Subjects in H/L impulsivity were randomly assigned to one of the two conditions (negative /control affect)</td>
<td>DEBQ, POMS, BIS-11</td>
</tr>
<tr>
<td>Lattimore &amp; Caswell, 2004</td>
<td>N=40 F</td>
<td>Between-subjects</td>
<td>Three consecutive tasks (active coping, passive coping, and control) with each 1 week interval</td>
<td>STAI, heart rate, blood pressure, DEBQ (R), taste-test</td>
</tr>
<tr>
<td>Lattimore &amp; Maxwell, 2004</td>
<td>N=119 F</td>
<td>Between-subjects</td>
<td>randomly assigned to one of four conditions (under two low cognitive load and two high cognitive load)</td>
<td>STAI, RS, a 10-point Hunger Scale, Taste test</td>
</tr>
<tr>
<td>Wallis &amp; Hetherington, 2004</td>
<td>N=38 F</td>
<td>Within-subjects</td>
<td>Countbalanced order: 1) neutral, 2) ego threatening, and 3) incongruent Stroop task.</td>
<td>Hunger-and mood-related measures on 100-mm VAS, PANAS, DEBQ, STAI-T, the Beck Depression Inventory (BDI), Perceived stress Scale, State Self-Esteem scale</td>
</tr>
<tr>
<td>Shapiro &amp; Anderson, 2004</td>
<td>N=153 F</td>
<td>Between-subjects</td>
<td>randomly assigned to RS, State self-esteem scale,</td>
<td>Stress condition: 17 anagrams (mostly)</td>
</tr>
<tr>
<td>Year</td>
<td>BMI (kg/m²)</td>
<td>Condition</td>
<td>Stress Questionnaire</td>
<td>Food Consumption</td>
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<tr>
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</tr>
<tr>
<td>2005</td>
<td>24.0±4.6</td>
<td>Stress or no-stress condition</td>
<td>Subjective units of distress (SUDS), Taste rating forms</td>
<td>Snack foods</td>
</tr>
<tr>
<td>Zellner et al., 2006</td>
<td>22</td>
<td>Experiment 1: N=34 F (17 no-stress group &amp; 17 stress group), mean age 22</td>
<td>Between-subjects Randomly assigned to stress or no-stress condition</td>
<td>The two lists of ten anagrams: solvable or unsolvable anagram</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Experiment 2: N=169 (41M, 128F), mean age 24</td>
<td>Self-reported questionnaire containing five questions about perceived stress</td>
<td>Four bowls of foods (chocolate candies, potato chips, roasted peanuts and red seedless grapes)</td>
</tr>
<tr>
<td>Zellner et al., 2007</td>
<td>20.37±1.75yrs, BMI 22.53±1.43</td>
<td>Between-subjects randomly assigned to stress or no-stress condition</td>
<td>Questionnaires for measuring stress, preference about the food they chose</td>
<td>Four bowls of snack foods (two healthy peanuts and grapes, two unhealthy potato chips and chocolate candies)</td>
</tr>
<tr>
<td>Goldfield et al., 2008</td>
<td>20.37±1.75yrs, BMI 22.53±1.43</td>
<td>A 2×2×2 mixed design</td>
<td>Food pleasantness on a 150mm VAS, hunger on a 100mm VAS, STAI, the</td>
<td>Stress condition: 3-minutes of anticipation of giving a speech</td>
</tr>
<tr>
<td>Study</td>
<td>N, Gender, Mean Age, BMI</td>
<td>Between-subjects Assignment</td>
<td>Manipulation</td>
<td>Measures</td>
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<tr>
<td>Newman et al., 2008</td>
<td>N=66 (33 each in the stress or control condition: 13 M, 20 F), mean age 21.60</td>
<td>Between-subjects randomly assigned to stress or no-stress condition.</td>
<td>Stress condition: preparing a 4-min presentation for 10 min. Control condition: circle every ‘t’ in a short piece of text for 10 min.</td>
<td>STAI, DEBQ, TFEQ-Restraint (R) &amp; Disinhibition (D), POMS, hedonic &amp; sensory characteristics of the foods on a 100mm VAS</td>
</tr>
<tr>
<td>Yeoman &amp; Coughlan, 2009</td>
<td>N=96 F (age 21.6±0.4yrs, BMI 22.4±0.4 kg/m²)</td>
<td>Between-subjects randomly assigned to one of the three conditions (Negative affect, Positive affect, and Neutral)</td>
<td>Three emotionally relevant 20 min films (Neutral, positive affect, negative affect)</td>
<td>Three emotionally relevant 20 min films (Neutral, positive affect, negative affect)</td>
</tr>
<tr>
<td>Taylor &amp; Oliver, 2009</td>
<td>N=25(20 F, 6 M), age 25.3±9.7yrs, BMI 22.8±2.3kg/m²</td>
<td>Between-subjects randomly assigned to exercise or passive session</td>
<td>Stroop word-colour interference task</td>
<td>FCQ-T, FCQ-S, Feeling Scale, Felt Arousal Scale</td>
</tr>
<tr>
<td>Wallis &amp; Hetherington, 2009</td>
<td>Study 1: N=89 F (age 18.4±0.6yrs, BMI 21.3±2.8 kg/m²)</td>
<td>Between-subjects randomly assigned to ego-threatening task or control</td>
<td>The stress-induced eating questionnaire, DEBQ, subjective sensations of appetite (hunger &amp; fullness) and mood (anxiety, relaxation, &amp; stress) on a</td>
<td>The stress-induced eating questionnaire, DEBQ</td>
</tr>
<tr>
<td></td>
<td>Study 2: N=26 F (age 27.4±3.3yrs, BMI 24.3±1.1 kg/m²). Categorised to H/L RE and H/L</td>
<td></td>
<td>DEBQ, subjective sensations of appetite (hunger &amp; fullness) and mood (anxiety, relaxation, &amp; stress) on a</td>
<td>DEBQ, subjective sensations of appetite (hunger &amp; fullness) and mood (anxiety, relaxation, &amp; stress) on a</td>
</tr>
<tr>
<td>Study</td>
<td>Sample Size</td>
<td>Methodology</td>
<td>Outcome</td>
<td>Note</td>
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<tr>
<td>Appelhans, 2010</td>
<td>N=34 (16 NW, BMI 22.1±1.8kg/m²; 18 obese, 32.7±1.6kg/m²)</td>
<td>Emotional eaters: between-subjects randomly assigned to stress or control condition.</td>
<td>100mm-VAS, PANAS: A modified Trier Social Stress Task for 30mins (serial subtraction, timed completion of challenging visuospatial puzzles, delivering a videotaped speech).</td>
<td>snack (dried fruit mix): No significant differences between task conditions. High RE suppressed overall food intake than URE.</td>
</tr>
<tr>
<td>Raspopow et al., 2010</td>
<td>N=48 (age 19.3±2.3yrs, BMI 23.9±4.7kg/m²)</td>
<td>Emotional eaters: classified to high or low emotional eaters.</td>
<td>DEBQ, hunger on an 11 point Likert scale, PANAS, Blood sampling for cortisol, Food choice task by presenting the name of foods: low-fat vs. high-fat (grapes, caramel rice crisps, Hershey Kisses, Carrot muffin)</td>
<td>Food choice task with the name of foods: No significant differences on the food choice between stressor condition or emotional eating status.</td>
</tr>
<tr>
<td>Lemmens et al., 2011</td>
<td>N=42 (26 F, 16 M/ 27 NW, 15 visceral overweight)</td>
<td>Emotional eaters: within-subjects randomly assigned to a stress test and rest test session.</td>
<td>TFEQ, POMS, STAI, appetite on a 100mm-VAS: A mathematical test × 2 times: 1) Stress condition: an unsolvable stress version + irritating + background noises 2) Control condition: solvable version without music and noises</td>
<td>‘Liking’ and ‘wanting’ computer test, meal type at 2 time points after a mathematical test: No differences in appetite between NW and visceral overweight subjects &amp; between the stress and rest condition. Visceral overweight people showed higher energy intake from the 2nd meal and higher ‘wanting’ for dessert and snacks in the stress condition compared to the control condition.</td>
</tr>
</tbody>
</table>

Note. M – males; F – females; NW – normal weight; DEBQ – the Dutch Eating Behavior Questionnaire; PANAS - the Positive and Negative Affect Scales; TFEQ – The Three Factor Eating Questionnaire; POMS – Profile of Mood States; RS - the Restraint Scale; STAI – the State-Trait Anxiety Inventory Scale; VAS - Visual Analogue Scales; MAACL - the Multiple Affect Adjective Check List; RE – restrained eaters / NRE – unrestrained eaters.
In Table 2.2, a total of 21 studies examined the relationship between naturalistic stress and eating-related variables by using self-reported questionnaires. Among the studies, 9 studies were survey-based cross-sectional studies by including recall of experiences and 12 studies were longitudinal studies over an average 13 weeks (range between 1 week and 48 weeks). Most naturalistic stress in the presented studies involved examination stress during an exam period and types of participants were limited to student groups and normal weight subjects. Only 1 study involved overweight subjects. Eighteen studies showed a greater energy intake or desire to eat during a period of stress. Two studies showed less energy intake and one study did not show any difference between a stress day and a control day. However, there are limitations of self-report measures (of stress and eating-related variables) and there is a lack of evidence for a causal effect from the studies presented in Table 2.2. The self-reported questionnaire may have not reflected true levels of stress or the amount of food eaten. Also, it is not clear whether stress causes the changes in eating-related behaviours or if there are other possible variables which may have had a confounding influence on the reported relationship. Thus, it may be difficult to determine whether chronic life stress contributed to an increase in food consumption or high-caloric food preferences or eating-related thoughts.

A total of 41 experimental studies are summarised in Table 2.3, in which stress was manipulated to test the causal effects on eating-related variables. There was a broader range of participants (e.g., age, BMI) than in the cross-sectional and longitudinal studies presented in Table 2.2, but only 6 studies involved overweight participants. The stressors used were physiological stress (e.g., electric shock, noise, ice-cold water), mental challenge (e.g., Stroop task, anagrams), cognitive stress (e.g., speech task) and manipulated mood (e.g., reading a story, films). Among the studies, 34 studies showed a greater energy intake or desire to eat during elevated stress, compared with control conditions. Three studies showed less energy intake and 4 studies showed no difference in energy intake compared with a control condition. However, laboratory studies from Table 2.3 also have some limitations. Most studies did not control prior eating before an experimental session and the acute stress may not have been sufficiently potent in an artificial situation in a laboratory. Although acute stress may not have a greater effect on eating behaviour compared with chronic stress, in terms of controlling potential variables an experimental study with acute stress may be beneficial to examine the causal effect between stress and eating-related variables.

Overall, most previous studies in Table 2.2 and 2.3 showed that stress and negative mood led to an increase in high-caloric food intake. However, stress-induced eating is a complicated process. Greeno and Wing (1994) suggested in the Individual-Difference Model (see Figure 2.11) that when stress is combined with other variables (e.g., gender, weight, personality), individuals will respond to stress differently. For example, restrained eaters may increase the intake of high fat
snack foods after an ego-threat task, but unrestrained eaters may not (Wallis & Hetherington, 2009).

2.3.5. Personality (impulsivity)

Two different mental processes are involved in decision making: One is ‘the impulsive mind’ with little thought of any consequences, another is ‘the self-controlled mind’ with reflective thought about the long-term consequences (Madden & Johnson, 2010). There are various definitions of impulsivity. Madden & Johnson (2010) defined it as a tendency to act on a whim and disregard a more rational long-term strategy for success and as such may be regarded as a personality trait. Also, it is defined as the inability to sustain attention (Dickman, 1993; Barrett & Patton, 1983), a dimension of the personality trait, extraversion (Eysenck, 1983), and the preference for immediate over delayed gratification (Rachlin & Green, 1972). It is also equated with the term ‘disinhibition’ (Verdejo-Garcia, Lawrence, & Clark, 2008). Disinhibiting of behaviours, urges, desires, or emotions are associated with the failure of self-regulation (Muraven & Baumeister, 2000; Baumeister & Heatherton, 1996). As such, impulsivity has been associated with addictive behaviours (Verdejo-Garcia et al., 2008).

Based on these definitions of impulsivity, the relationship between impulsivity and problematic eating behaviour can be discussed from two distinct aspects: disinhibited and reward driven behaviour. Disinhibition is a common characteristic of impulsivity. It is shown in people who have difficulty in restraining behaviours/responses when they may wish to inhibit. Impulsive people tend to be more vulnerable to unhealthy eating behaviour and overeating. For example, Nederkoorn, Smulders, Havermans, Roeef, and Jansen (2006) and Nasser, Gluck, and Geliebter (2004) found that obese women and children are more impulsive than those of normal weight. Also, high-impulsives showed a higher food intake than low-impulsives (Guerrieri, Nederkoorn, Stankiewicz, Alberts, Geschwind, Martijn, & Jansen, 2007). Further, Jansen and colleagues (2009) found a strong effect of impulsivity on the consumption of tasty high-caloric food when combined with being a restrained eater. They reported that high-restrained eaters overeat particularly when they are also impulsive.

The other aspect of impulsivity, reward driven behaviour, is also linked to addictive behaviours, and overeating and weight gain. Impulsive people who have this tendency are likely to be sensation seekers, to engage in risky behaviours, and to have a lessened ability to delay gratification (Davis, 2009). In terms of sensitivity to reinforcement (reward), Davis (2009) found strong associations between reward-based impulsivity and overeating. In his unpublished data, obese individuals, in contrast to normal weight individuals, preferred smaller immediate rewards to delayed larger rewards. Although other addiction studies (Dallery & Raiff, 2007;
Reynolds, 2006) report that delayed discounting predicts addictive behaviours (e.g., cigarette smoking), there is no clear evidence whether higher rates of discounting can predict food craving. However, studies about the relationship between obesity and delayed discounting (Rasmusseen, Lawyer, & Reilly, 2010; Epstein et al., 2010; Weller, Cook III, Avsar, & Cox, 2008) may suggest that impulsivity could predict food craving, as delayed discounting is related to reinforcement, which predicts energy intake. Furthermore, by using functional magnetic resonance imaging, Beaver and colleagues (2006) supported the idea that high-impulsive people find it harder to resist high-caloric palatable food. They found that trait reward sensitivity (according to a self-report questionnaire; BAS) was highly correlated with neural responses to images of appetizing food (e.g., chocolate cake, pizza) in a fronto-striatal-amygdala-midbrain network.

The studies mentioned above indicate previous research has found that impulsivity is highly related to unhealthy behaviour, and that for high-impulsive people it is more difficult to resist palatable food than for low-impulsive people. Thus, impulsivity may be regarded as an important factor that influences food craving, interest and consumption.

2.3.6. Other health risk behaviour and food consumption

There is some support for a clustering of unhealthy behaviours. For example, Fine and colleagues (2004) reported that about 92% of smoking respondents tend to also engage other unhealthy behaviours (i.e., inactivity, drinking alcohol). In surveys (Chiolero, Wietlisbach, Ruffieux, Paccaud, & Cornuz, 2006; Wilson, Smith, Speizer, Bean, Mitchell, Uguy, & Fries, 2005; see a review by Chiolero, Faeh, Paccaud, & Cornuz, 2008), smokers showed that they were less likely to do exercise, eat fruit/vegetables, and were more likely to drink excessively and have multiple risky behaviours than non-smokers. A clustering of unhealthy behaviours may have influenced by socio-economic and environmental factors (Drieskens, Van Oyen, Demarest, Van der Heyden, Gisle, & Tafforeau, 2010), socialisation, and psychological factors (e.g., impulsivity, poor self-regulation linked to stress and low mood) (Roberfroid & Pomerleau, 2001; Bonnet, Irving, Terra, Nony, Berthezene, & Moulin, 2005).

There are widely held beliefs among smokers that smoking can help control weight and thus giving up smoking will lead to weight gain (Jenks & Higgs, 2010; 2007; Facchini, Rozensztejn, & Gonzalez, 2005; Pomerleau, Pomerleau, Namene, & Mehringer, 2000). Evidence shows that weight gain may be considered as a consequence of smoking cessation (see review papers by Spring, Howe, Berendsen, McFadden, Hitchcock, & Rademaker et al., 2009; Spring et al., 2003; Pisinger & Jorgensen, 2007a, 2007b; Caan, Coates, Schaefer, Finkler, Sternfeld, & Corbett, 1996; Pomerleau, Ehrlich, Tate, Marks, Flessland, & Pomerleau, 1993). Pisinger and Jorgensen
(2007a; 2007b), in a prospective intervention study, tracked smokers for 1 year and the smokers were grouped as non-smokers and continuous smokers to examine the change in waist circumference and weight concern. They found that the waist circumference increased by 3.9cm and there was a 4.3kg gain in quitters at 1year follow-up, compared with those who remained smoking. Also, quitters reported to be more concerned with their weight than smokers and a considerable difference was shown between female ex-smokers and smokers. Pisinger and Jorgensen (2007b) also found that 52% of women and 32% of men with a previous quit attempt mentioned weight gain as a reason for relapse. In a longitudinal study, Lycett, Hajek, and Aveyard (2010) examined the weight change of the different smoking status groups (i.e., abstainers, smokers, relapsed, later abstainers) over 8 years. They found that the abstainers showed the biggest weight change gaining nearly 9kg over 8 years, whereas smokers and relapsed smokers gain about 2kg over 8 years. Also, late abstainers, who smoked during the first year but were abstinent at 8 years, gained 8.33kg.

Only a few studies have shown a change in food craving after smoking cessation. For example, DiLorenzo, Walitzer, Sher, and Farha (1991) recruited 16 quitters, 11 smokers, and 16 non-smokers to examine the effect of smoking cessation on food craving. At baseline, after 1 week and after 5 weeks (and on each day) participants were exposed to a high-caloric food and an ad libitum food consumption taste-rating task. They found that the quitters increased craving during ad libitum consumption and had a weight gain of about 5lbs, compared with two control groups (smokers and non-smokers). Hatsukami and colleagues (1993) also supported the previous study; with quitters increasing total caloric intake compared with those who continued to smoke. In an experimental study (Spring, Pagoto, McChargue, Hedeker, & Werth, 2003), smokers and non-smokers were involved in a computer based reinforcing value task (the Apple Picker), during continuous smoking and 48 hours abstaining from smoking. The earned points were exchangeable for snack foods. The results showed that smokers, while nicotine deprived increased their effort to earn snack foods compared with non-smokers.

There is some evidence to explain how smoking cessation is related to increased snacking. Mineur, Abizaid, Rao, Salas, DiLeone, & Gündisch et al. (2011) found that smoking may lead to nicotine-induced decreases in appetite and control body weight through activation of the hypothalamic melanocortin system. Contrary to the common beliefs among smokers that smoking may reduce the sensitivity of a hunger signal, nicotine deprivation among abstainers may increase hunger because of a loss of a suppressant effect on appetite (Perkins, Mitchell, & Epstein, 1995, Perkins, Epstein, Stiller, Fernstrom Sexton, & Jacob et al., 1991). Nicotine deprivation induced stress may also be a possible reason for increasing high energy dense foods (e.g., chocolate), which may have a mood enhancing effect (Radin et al., 2007) and may play a role as a substitute for a cigarette (Logue, 1996). Furthermore, a reward deficiency state which
is caused by nicotine deficiency may be altered to a desire or a wanting for snack foods, which is related to reward or reinforcing value (Spring et al., 2003; Epstein, Bulik, Perkins, Caggiula, & Rodefer, 1991).

2.4. Measurement issues

The previous sections have focused on the definitions of some of the key concepts of interest in addictive behaviours and factors associated with such behaviour. The following section considers how some of these concepts have been operationalised in food-related studies and provides a background to the measures of food consumption, food craving, and impulsivity.

2.4.1. Measure of food consumption

2.4.1.1. Observation (actual amount eaten)

In laboratory-based research, food consumption has been measured by *ad libitum* eating (Appelhans, 2010; Martin, O’Neil, Tollefson, Greenway, & White, 2008; Polivy, Coleman, & Herman, 2005) in an attempt to simulate natural environments where eating may occur. To assess *ad libitum* eating, Appelhans (2010) provided pre-weighed bowls of food (e.g., icecream, snacks) and asked subjects to rate the taste of them. They were left alone for about 10 min to give them enough time to consume the food. After the task, the food was weighed again to measure the consumption of the food. Yeomans and Coughlan (2009) also used two preweighed snack foods (popcorn and raisins). To simulate a naturalistic situation, the food was presented during a 20min film presentation. The participants were required to complete a taste test for the foods at the end of the film. They were told that they could consume as much of the foods as they liked. Although this method aims to assess actual eating behaviour there are some methodological problems. As mentioned above, most *ad libitum* eating was set in a laboratory (not actual living place), which may create artificial conditions, and subjects may keep being aware of taking part in the test. Those uncomfortable situations may have an influence on subject’s behaviour and decision making, then it will be difficult to measure unconscious food intake. However, participants were instructed for *ad libitum* eating that all uneaten food would be discarded (Appelhans, 2010) or that they were required to complete a taste test and were welcomed to consume as much of the food as they liked in the meantime (Yeoman & Coughlan, 2009). Gregersen and colleagues (2008) state that the *ad libitum* energy intake method is useful but the method may need to be used with other methods (e.g., self-reported measures).
2.4.1.2. Self-report

Food consumption has also been measured using a self-reported format with a single item or 24 hour recall (Wallis & Hetherington, 2009; Cartwright, Wardle, Steggles, Simon, Croker, & Jarvis, 2003; Wardle et al., 2000). Wallis and Hetherington (2009) asked participants to complete a self-reported eating questionnaire which required reporting the amount of snack foods (crisps, chocolate, biscuits) eaten around the time of the specific stress experience. However, the response options were relative to the usual amount of food eaten (e.g., ‘more than usual’), rather than reporting a numerical amount (e.g., 100g of chocolate). Cartwright and colleagues (2003) used food frequency questionnaires for measuring the overall quality of diet in a large survey. It consisted of a question “How often do you eat....?” for 34 food items (e.g., crisps, sweets/chocolate, biscuits) with a 6 point scale (i.e., never, less than once a week, once or twice a week, most days, once a day, and more than once a day). Another assessment for food consumption is the 24 hour recall (Wardle et al., 2000). Participants were asked to write down all the food they consumed over the previous 24 hours and based on the information via a nutrient analysis program nutrient composition of foods were calculated (e.g., total fat).

2.4.2. Measures of food craving and attentional bias

The measurement of food craving will be discussed in terms of direct (e.g., self-report) and indirect measures (e.g., attentional bias).

2.4.2.1. Direct measures using self-report

The most common method of measuring food craving is by questionnaire to assess either general tendencies (i.e., trait) or situation and time specific responses (i.e., state). There are some questionnaires to measure trait food craving such as the Food Craving Inventory (FCI)(White, Whisenhunt, Williamson, Greenway, & Netemeyer, 2002), the Food Craving Questionnaire-Trait (FCQ-T)(Cepeda-Benito, Gleaves, Williams, & Erath, 2000b), the Attitudes to Chocolate Questionnaire (ACQ)(Benton, Greenfield, & Morgan, 1998) and state food cravings (FCQ-S and the 100mm Visual Analogue Scale).

Trait food craving.

FCQ-T. This trait questionnaire was developed by Cepeda-Benito and colleagues (2000b) and it consists of 39 items with 9 subscales, reflecting possible precipitants and consequences of food craving, using a Likert scale ranging from 1 (never or not applicable) to 6 (always). The 9 subscales are: 1) intentions and plans to consume food (3 items); 2) anticipation of positive
reinforcement that may result from eating (5 items); 3) anticipation of relief from negative states and feelings as a result of eating (3 items); 4) possible lack of control over eating (6 items); 5) thought or preoccupation with food (7 items); 6) craving as a physiological state (4 items); 7) emotions that may be experienced before or during food cravings or eating (4 items); 8) environmental cues that may trigger food cravings (4 items); and 9) guilt that may be experienced as a result of cravings and/or giving into them (3 items). This questionnaire measures food cravings that are stable across time and situations.

The FCQ-T has been modified depending on the focus of the research. For example, the G-FCQ-T measures a general craving for food and the Food Chocolate-Craving Questionnaire Trait (FCCQ-T) is the chocolate version of the FCQ-T. The FCQ-T is extensively validated and available in Dutch (Franken & Muris, 2005), English (Cepeda-Benito et al., 2000b), and Spanish (Cepeda-Benito et al., 2000a). The FCQ-T has consistently been shown to have acceptable reliability and construct validity. With a non-clinical population (Cepeda-Benito, Fernandez, & Moreno, 2003), the overall alpha reliability was 0.93 and factor derived sub-scale alpha coefficients ranged from 0.68-0.90. Its test-retest reliability has also been shown to be acceptable among overweight and obese populations (Vander Wal, Johnston, & Dhurandhar, 2007). The biggest advantage of FCQ-T is that it provides multidimensional assessment of cravings, which may make this questionnaire to be more sophisticated and more flexible than other trait questionnaires (e.g., ACQ).

ACQ. Benton and colleagues (1998) developed the ACQ to assess the causes and consequences of chocolate eating. The original questionnaire contained three factors: 1) craving or preoccupation with chocolate; 2) guilt experienced after eating chocolate; 3) functional use of chocolate. The final version of the ACQ contains 24 items selected from 80 original items using a Visual Analogue Scale (a 100 mm line) with ‘not at all like me’ at one end and ‘very much like me’ at the other. However, Cramer and Hartleib (2001) suggested a two-factor model for the ACQ, with only craving and guilt. In a study by Fletcher and colleagues (2007), these two factors (craving and guilt), by using a modified 5 Likert Scale (1 = strongly disagree, 5 = strongly agree), were used to examine the difference in chocolate craving between restrained eaters and non-restrained eaters. Muller, Dettmer, and Macht (2008) evaluated the ACQ by comparing it with the Dutch Eating Behavior Questionnaire (Van Strien, Frijters, Bergers, & Defares, 1986a). They found a significant correlation between ‘guilt’ and ‘emotional and restrained eating’ and between ‘craving’ and ‘emotional and external eating’. Overall though there have been a limited number of studies that have used the ACQ, and further research is needed to determine its psychometric properties.
The Food Craving Inventory (FCI; White et al., 2002) was designed to measure cravings for 28-specific types of food (namely: high fat, sweets, carbohydrates/starches, and fast-food fats) by using two subscales: subjective cravings and consumption of particular foods. The first subscale (subjective) assesses the frequency of subjective craving (“Over the past month, how often have you experienced a craving for the food?”) on a 5-point Likert scale ranging from 1 (‘not at all’) to 5 (‘nearly every day’). The second subscale (behavioural) measures the extent to which participants gave in to craved food (“Of those times in the past month during which you craved a particular food, how often did you give in to the craving and eat the food?”) on a 5-point Likert scale. White and colleagues (2002) examined the reliability and validity of the questionnaire, and they found a positive correlation between the high fats scale and BMI. The FCI may be useful to use to measure overeating and binge eating.

State food craving.

FCQ-S. This is similar to the FCQ-T, albeit worded to capture cravings at a particular moment in time (Cepeda-Benito, Gleaves, Williams, & Erath, 2000b). For the FCQ-S, participants are asked to answer with each statement ‘right now, at this very moment’ using a 5-point Likert scale ranging from 1 (‘strongly agree’) to 5 (‘strongly disagree’). The FCQ-S consists of 15 items with five factors: 1) an intense desire to eat; 2) anticipation of positive reinforcement that may result from eating; 3) anticipation of relief from negative states and feelings as a result of eating; 4) obsessive preoccupation with food or lack of control over eating; and 5) craving as a physiological state. The FCQ-S also can measure general food craving or special food craving (e.g., chocolate) and has been translated into several languages. Vander Wal and colleagues (2007) examined the construct validity of the FCQ-S with 28 overweight females. Participants completed the FCQ-S 15, 90, and 180 min after finishing the prepared breakfast. They found that the FCQ-S was sensitive to state changes in food craving. As the only multi-item measure of state food cravings (Vander Wal et al., 2007), the FCQ-S has been commonly used in food craving studies (e.g., Taylor & Oliver, 2009; Nijs, Franken, & Muris, 2007).

VAS. A Visual Analogue Scale (VAS) (Flint, Raben, Blundell, & Astrup, 2000; Chaput, Gilbert, Grengersen, Pedersen, & Sjodin, 2010) is widely used to quantify subjective food craving with lines of varying length (e.g., 100 mm, 150 mm). The VAS consists of a line with anchors at each end (‘no craving at all’/’extremely craving’). Participants are asked to make a mark across the line corresponding to their cravings, and the level of craving is measured by measuring the distance from the left end of the line to the mark. Unlike other questionnaires that measure food craving with several subscales and multiple-items, the VAS measuring food craving can also be used to assess hunger and appetite (e.g., Flint et al., 2000). However, the VAS as a single item measure may not adequately represent the multidimensional nature of cravings (Chaput et al., 2010; Mattes, Hollis, Hayes, & Stunkard, 2005; Flint et al., 2000).
2.4.2.2. Implicit measures (attentional bias)

*Measures of attentional bias.* Field and Cox (2008) state that attentional bias provides an objective indication of motivational state and state food craving. There are several ways of measuring attentional bias such as the Stroop task (see a review paper by Dobson & Dozois, 2004), the dot probe task (Hepworth, Mogg, Brignell, & Bradley, 2010; Brignell et al., 2009; Kemps & Tiggemann, 2009), an eye-tracking system (Castellanos et al., 2009), and eyeblink response (Rejeski, Blumenthal, Miller, Lobe, Davis, & Brown, 2010). According to the Incentive-Sensitization Theory (Robinson & Berridge, 2000, 2003), the basic idea of attentional bias is that food cues guide an individual towards appetitive stimuli and the activation of reward systems elicits cognitive and behavioural responses such as food cravings and eating.

The dot probe and eye-tracking measures of attentional bias use a pair of food cues such as food/neutral pictures or words to compare the direction of a subject’s attention. Attentional bias with the dot probe task is quantified by calculating reaction time to food related cues and neutral cues. For example, in one study (Brignell et al., 2009), 19 high-external eaters (eating in response to environmental cues rather than internal hunger state) and 24 low-external eaters were involved in a visual probe task, which consists of 160 critical trials (eight presentations of the 20 food-control picture pairs) and 80 filler trials. The images were presented for 500 or 2000 ms. Attentional bias scores were calculated by subtracting the mean reaction time for probes replacing food pictures from the mean reaction time for probes replacing control pictures. They found that high-external eaters showed a significantly greater attentional bias for food cues than low external eaters. With an eye tracker, Castellanos and colleagues (2009) examined attentional bias for food-related images among normal weight and obese people. Participants’ eye movements were tracked while presenting paired food/non-food images for 2000 ms and gaze fixation recorded every 16 ms. Fixation direction and gaze fixation on either food or non-food images were calculated for attentional bias. They found that the group differences were shown in the fed condition and obese individuals gazed more and spent more time on food images than non-food images, compared with normal weight. In a recent trial, Rejeski and colleagues (2010) assessed attentional bias to food after 6 hours of food deprivation by using Eyeblink EMG. Eyeblink EMG responses were measured from the orbicularis oculi muscle to measure startle response after startle stimuli (100 dB(A) noises). Although food cues cause a higher level of state craving, they did not find significantly faster startle responses to food cues.

Studies have compared the different measures of attentional bias and found correlations between the measures (i.e., the dot probe task and eye tracking system) (Field, Mogg, & Bradley, 2004; Mogg, Field, & Bradley, 2005; Mogg, Bradley, Field, & De Houwer, 2003). For instance, Field and colleagues (2004) examined the effect of nicotine deprivation on attentional bias for
smoking cues by using a visual dot probe task and eye tracker. They found that fixation direction and gaze duration from the eye tracker and reaction time from the dot probe task indicated that smokers had higher attentional bias for smoking cues than control images. The results were consistent across the different measures. However, Pothos and colleagues (2009) compared five different measures of cognitive bias (i.e., dot probe, emotional Stroop, recognition, Extrinsic Affective Simon Task, explicit attitudes) for food stimuli and the correlation results indicated that the relationship between the measures was weak. The authors concluded that different cognitive bias measures did not correspond to the same psychological process and were careful to generalise the conclusion to other types of behaviour as the cognitive bias was limited to only food-related stimuli. Evidence about the relationship between different attentional bias measures is limited, but overall most studies have found a consistent result between the measures.

2.4.3. Measures of impulsivity

Verdejo-Garcia and colleagues (2008), in a review paper, reported that the relationship between impulsivity and substance abuse is evident across several types of drugs (e.g., alcohol, opiates) and measures of impulsivity (e.g., self-report, behavioural measures). Impulsivity has commonly been measured in two ways as a dimension of personality: (1) using self-report measures (e.g., Harrison, Coppola, & McKee, 2009; Reynolds, Patak, Shroff, Penfold, Melanko, & Duhig, 2007), (2) using experimental tasks (e.g., Guerrieri et al., 2007; Vassileva, Gonzalez, Bechara, & Martin, 2007).

2.4.3.1. Self-report measures

There are several self-report questionnaires to assess impulsive personality such as the Impulsiveness Questionnaire (I-7; Eysenck et al., 1985), The Barratt Impulsivity Scale (BIS-11, Patton, Stanford, & Barratt, 1995), Impulsivity Inventory (DII; Dickman, 1990), The Behavioural Inhibition System and Behavioural Activation System (BIS/BAS Scales, Carver & White, 1994) and the UPPS Impulsive Behaviour Scale (UPPS; Whiteside & Lynam, 2003, 2001). Among these questionnaires, BIS-11 and UPPS have been widely used in addiction studies.

BIS-11. BIS-11 is a 30-item questionnaire and was designed to assess three dimensions: (1) attentional (8 items, e.g. ‘I don’t pay attention’); (2) motor (11 items, e.g. ‘I do things without thinking’); and (3) non-planning impulsiveness (11 items, e.g., ‘I plan tasks carefully’). The original concept of this scale was closely linked to Eysenck’s Extraversion dimension in the
Eysenck Personality Questionnaires (Eysenck & Eysenck, 1978). It is based on an integrated model of impulsivity which includes cognitive, social, and behavioural elements (Miller, 2003). Miller, Joseph, and Tudway (2004) examined the component structure of impulsivity from four self-report measures of impulsivity (i.e., I-7, BIS-11, DII, BIS/BAS). They concluded that the measures have a multi-dimensional construct and the three components of BIS-11 represent three sub-factors of a more general impulsivity factor. Their findings have shown how this scale relates to other measures of impulsivity.

Recently, Spinella (2007) introduced a 15-item short form of the BIS (BIS-15) which has the same 3-factor structure (each with 5 items) as the BIS-11. The scales showed good reliability and validity, and was highly correlated with the original scale (r= .94, p < .01) among several psychiatric populations. However, BIS-11 has been examined in both clinical and non-clinical subjects to determine its psychometric properties (see a review by Stanford, Mathias, Dougherty, Lake, Anderson, & Patton, 2009; Patton et al., 1995), whereas BIS-15 has not yet been fully validated in non-clinical populations. One study, Orozco-Cabal, Rodriguez, Herin, Gempeler, and Uribe (2010), confirms the validity and reliability of BIS-15 in Spanish with clinical and non-clinical population.

BIS-11 has been used in several addiction studies to measure trait impulsivity. For example, in a cue reactivity study, Doran and colleagues (2007) revealed that the BIS-11 predicted increases in cigarette cravings following exposure to a smoking cue. Harrison and colleagues (2009) used the BIS-11 to assess the relationship of trait impulsivity and nicotine deprivation (5hrs or 17hrs) related changes in cognitive processing among 30 daily smokers. They hypothesised that higher impulsive people might experience greater changes after the deprivation. However, the results showed that more impulsive individuals were less affected by nicotine deprivation on performing cognitive task. In a smoking study by Reynolds and colleagues (2007), BIS was used to compare smokers and non-smokers. They found that adolescent daily smokers showed higher impulsivity than non-smokers. Other studies using BIS found that impulsivity was related to food intake. For instance, Guerrieri and colleagues (2007) hypothesised that impulsive participants will consume more calories (more sugar beans) during a bogus taste test. Participants were classified as high or low-impulsive by using a median-split of the BIS score. They found that high-impulsives ate significantly more sugar beans than low-impulsives.

**The UPPS.** This measure of impulsivity consists of 45-items with four subscales: (1) urgency (e.g., “When I feel bad, I will often do things I later regret in order to make myself feel better now.”); (2) sensation seeking (e.g., “I quite enjoy taking risks.”); (3) lack of perseverance (e.g., “I tend to give up easily.”); (4) lack of premeditation (e.g., “My thinking is usually careful and purposeful.”). Whiteside and Lynam (2001) state that the scale has good internal consistency,
with Cronbach’s alpha coefficients ranging from .83 to .91 for the subscales, and the correlations between subscales are modest ($r = .22$). This scale has successfully been used to discriminate between different groups (e.g., control group vs. substance abuser such as alcoholics)(Whiteside, Lynam, Miller, & Reynolds, 2005). Some smoking studies (Doran, Cook, McChargue, Myers, & Spring, 2008; Doran, Cook, McChargue, & Spring, 2009) tested the effect of impulsivity on affective responses following smoking cue exposure. In both studies, internal consistency for the UPPS subscales in their sample ranged from about .78 to .91 and the average correlation between the four subscales was around $r = .30$. They found that higher levels of impulsivity (urgency and sensation seeking) were associated with higher levels of negative affect following exposure to the smoking cue. Although the psychometric properties of the measure appear to be good, it may be difficult to use with so many items.

In summary, various self-report measures exist for measuring trait impulsivity. Each scale has a different theoretical basis and dimensions of impulsivity. Thus, a researcher has to choose the one that best fits the planned research.

2.4.3.2. Experimental tasks

Guerrieri and colleagues (2007) stated that self-report measures capture a person’s biases and inaccuracies, compared to behavioural measures. Unlike self-reported measures, behavioural measures are regarded as direct measurements that capture state impulsivity, using laboratory tasks. Typically they measure performance in terms of reaction time and accuracy. Two types of task have been commonly used in substance abuse studies: 1) measures of response inhibition, including the Stop Signal task, Go/No Go task, and the Stroop test; 2) measure of delay discounting task. Although each measure captures impulsivity on the task at a particular moment in time it is assumed that it provides an indicator of how impulsive someone would generally be.

1) Measures of response inhibition

*Stop Signal Task and Go/No Go task.* These tasks assessing response inhibition come from the Stop Signal paradigm (Logan & Cowan, 1984), which consists of a go task and a stop task. Subjects are normally given a go task (e.g., 75% of trials) to perform and occasionally a stop signal (e.g., 25% of trials) is presented. The go task is a choice reaction time task in which participants are required to press a certain key as fast as possible (Logan, Schachar, & Tannock, 1997). In the Stop Signal Task, participants are asked to discriminate an X from an O and press the right key for X and the left key for O. Guerrieri and colleagues (2007) adapted the Stop Signal task from Logan’s study. The learned response for a go task had to be inhibited when an
auditory tone (for 250 ms) was heard. The levels of task difficulty were controlled by the individual’s response. Initial delay time between the go signal and the stop signal (a tone) was set to 250 ms. If a participant inhibited successfully on the task, the task was made more difficult by increasing the delay by 50 ms. If the inhibition was unsuccessful, the delay decreased by 50 ms to make the task easier. While performing, reaction time and stop delay (inhibited the go response when they got a stop signal) were measured. The Stop signal reaction time (SSRT) is calculated by subtracting the stop delay from the reaction time: The longer the SSRT the more impulsive a participant is supposed to be.

There are several designs of the modified Go/No Go task with various types of stimuli such as numbers and letters (Reynolds et al., 2007), with different colours (Mostofsky, Schafer, Abrams, Goldberg, Flower, & Boyce et al., 2003), with high and low noise tone (Fuentes, Tavares, Artes, & Gorenstein, 2006), and with emotional face expressions (Schulz, Fan, Magidina, Marks, Hahn, & Halperin, 2007). Typically it consists of two stimuli (Go and No Go) and participants are instructed to respond as quickly as possible by pressing a key. The response inhibition is measured by the ability to withhold responding to a No Go stimuli. Dinn et al (2004) designed the Go/No go task with two stimuli (a 2 x 2 cm blue square for Go stimuli and cross for No Go stimuli). Participants were required to respond when the blue square was shown and withhold their response when the blue cross appeared. The inter-stimulus interval was randomly adjusted with different timing intervals such as 100, 250, 400, 500, 750, 1000, or 2000 ms. In a smoking study (Harrison et al., 2009), a cued Go/No go task was designed: a fixation slide (+) was presented for 800 ms, followed by a white blank screen for 500 ms. A green (Go stimuli) and blue rectangle (No go stimuli) were presented and participants were asked to press a key (/) on a Go stimuli and withhold a response on a No-go stimuli. The greater the number of errors indicated greater impulsivity (poor inhibitory control) and longer RT showed slower response activation on the task.

The Stroop Task. The Stroop Colour-Word Task has also been widely used to measure inhibition (of impulsivity) (Vassileva et al., 2007; Lansbergen, Van Hell, & Kenemans, 2007; Mintzer & Stitzer, 2002; Verdejo-Garcia et al., 2008). In their study, participants were asked to name or press a key matching with the word’s colour which may be either incongruent or congruent with the word. They were instructed to respond as quickly and accurately as possibly. Thus, the difference in reaction time (msecs) on incongruent and congruent trials provides an interference score, related in part to the inhibition of an automatic tendency to read the word (e.g., delayed response / increased reaction time reflects inhibition).
2) Delay discounting task

The idea of delay discounting is that the value of delayed reward is discounted in inverse proportion to its delay, and the degree of discounting due to a delay can imply an individual’s impulsivity. The approach of the delay discounting task is to study preference between smaller-sooner and larger-later consequences (Madden & Johnson, 2010). Thus, impulsive individuals tend to choose immediate smaller rewards more frequently than do non-impulsive individuals. Reynolds (2006) categorises the delay discounting task in at least three categories including hypothetical, real-reward, and real-time measures. Hypothetical measures are the most commonly used and involve imaginary delays and rewards about choice preference between larger monetary amounts that are delayed and smaller amounts that are immediate. Real-reward measures are built on hypothetical measures to improve validity. These measures give one choice response randomly selected from all choices during the task and the subjects receive either immediate or delayed money based on one’s choice. The real-time measures let participants experience all choice results in real time. Reynolds (2006) states that real-time measures are useful to examine short-term increases or decreases in delay discounting. The delay discounting task has been used in several drug addiction studies.

In smoking studies, cigarette smokers show steeper discounting of monetary outcomes than do non-smokers (Johnson, Bickel, & Baker, 2007; Reynolds et al., 2007). The same results are shown in alcohol addiction studies (Field, Christiansen, Cole, & Goudie, 2007; Petry, 2001). People who need treatment for drug abuse are not likely to be able to wait for delayed benefits that result from drug abstinence and may need immediate outcomes to bridge the delay. Delay discounting research suggests that the task can be a predictor of drug-seeking behaviour (problematic behaviours). However, the delay discounting task has seldom been used in studies related to food craving. Odum, Baumann, and Rimington (2006) and Odum and Rainaud (2003) reported that food is a primary reinforcer and money is a conditioned reinforcer, thus food may be discounted more steeply than money. In terms of objective value, food is perishable and loses value over time. Rasmussen, Lawyer and Reilly (2010) also noted that people tend to depreciate consumable/perishable commodities (e.g., food, alcohol, drugs) at shorter delays than non-consumable commodities (e.g., money). However, the evidence using the delay discounting task is limited, especially in snacking studies, and there is a need to examine whether it is possible to compare perceived reward from food and money directly.
2.5. The effects of exercise on eating behaviours and related constructs

In this section, the effect of exercise on a range of eating-related variables (e.g., appetite, hunger, energy intake, and food cravings) will be considered. Although many studies have attempted to examine the effects of exercise on food intake and the regulation of energy balance, the evidence and causal mechanisms are not clearly understood. Thus, it is important to determine what happens to eating behaviour after involvement in an exercise session. Some of the research on chronic effects from training studies will be reviewed but the main focus will be on the acute effects of a single session of exercise to fully inform the research in this thesis.

2.5.1. Overview of previous studies

Several review papers (Hopkins, King, & Blundell, 2010; Martins, Morgan, & Truby, 2008a; Blundell, Stubbs, Hughes, Whybrow, & King, 2003; Bellisle, 1999; Blundell & King, 1999; King, 1999; 1998; King, Tremblay, & Blundell, 1997b) have reported on the acute and chronic effects of exercise on appetite control. Only a few studies have examined the effect of chronic exercise on eating behaviours. King and colleagues (1997b) reviewed 19 long-term intervention studies and 42.1% of the studies revealed that there was no compensation of energy intake. Also, Blundell and King (1999) found that 26.7% of long-term intervention studies (n = 15 studies), reported a decrease in energy intake, 60% showed no change, and 13.3% showed an increase in energy intake. Overall, review papers reported that most previous long-term studies have shown either no changes in energy intake or decreases in energy intake, and only a few studies have shown increases in energy intake.

In a recent study (Martins, Kulseng, King, Holst, & Blundell, 2010) involving twenty-two sedentary overweight and obese people, a 12-week supervised exercise programme (5 times/week, 75% Max HR) induced a reduction in body weight and postprandial insulin plasma levels, increased acylated ghrelin plasma levels, and delayed release of glucagon-like peptide-1. Further, Stubbs and colleagues (2002a, 2002b), using a within-subject cross-over design, did not find exercise-induced changes in subjective feelings of hunger over a 7-day exercise programme compared with a control condition.

Acute studies have also revealed mixed findings regarding changes in eating behaviours. The review by Blundell & King (1999) on the acute effects of exercise on appetite and energy intake, over a few subsequent days (no longer than 2-5 days), revealed that 19% of such studies reported an increase in energy intake after exercise (e.g., Durrant, Royston, & Wloch, 1982; Verger & Lanteaume, 1994; Verger, Lanteaume, & Louis-Sylvestre 1992), 65% showed no change (e.g., Lluch, King, & Blundell, 1998), and 16% showed a decrease (e.g., Kissileff, Pi-
Variation in the changes in energy intake following exercise can be explained by several possible mechanisms, including physiological (e.g., homeostatic system) or psychological (e.g., health beliefs) compensatory mechanisms.

As a homeostatic system, according to the ‘set point model’ (Wirtshafter & Davis, 1977), body weight and composition requires the achievement of a steady state in which the amount of energy consumed is equal to the amount of energy burned. In other words, energy expenditure during exercise should be specifically replaced by intake of food (mostly CHO or fat). However, decreased energy intake may be characterised by exercise induced short-term anorexia (suppression of hunger). The reduction of energy intake after exercise may be caused by the changes of energy balance hormones (e.g. acylated ghrelin, peptide YY, Glucagon-like-peptide 1) (Ueda, Yoshikawa, Katsura, Usui, & Fujimoto., 2009a; Ueda, Yoshikawa, Katsura, Usui, Nakao, & Fujimoto, 2009b; Martins, Morgan, Bloom, & Robertson, 2007a; Broom, Stensel, Bishop, Burns, & Miyashita, 2007; Scheurink, Ammar, Benthem, van Dijk, & Sodersten, 1999) and increased body temperature (Stanier., 1977; Andersson & Larsson, 1961). Regarding the appetite regulation mechanism, Long, Hart, and Morgan (2002) state that exercise may increase the short-term regulation of food intake by increasing sensitivity to satiety signals and insulin sensitivity.

Psychologically, the ‘Compensatory Health Beliefs Model’ (Rabiau, Knauper, & Miquelon, 2006; Knauper, Rabiau, Cohen, & Patriciu, 2004) suggests that unhealthy behaviour can be compensated for (or ‘neutralised’) by engaging in other healthy behaviour. King (1999) noted that any increased absolute energy intake in response to acute exercise could also be possibly influenced by cognitive factors such as beliefs (e.g., ‘exercise makes you hungry’). On the other hand, exercise may also help to regulate energy intake by enhancing mood (Maraki, Tsofliou, Pitsiladis, Malkova, Mutrie, & Higgins, 2005; Hsiao & Thayer, 1998; Thayer, Newman, & McClain, 1994; Thayer, Peters III, Takahashi, & Birkhead-Flight, 1993). The effect of exercise on affect will be introduced in more detail in a later section.

The summaries of the effects of acute exercise on eating behaviours are shown in Table 2.4. The review table built on review tables by Blundell and King (1999) and King and colleagues (1997b) and added more studies based on recent review papers (Hopkins et al., 2010, Martins et al., 2008a) and by searching studies in Medline and Pubmed using search terms (exercise OR snacking OR appetite OR energy intake OR energy balance). This review table was aimed to accumulate a wide range of literature on the link between exercise and eating-related variables. It was not to conduct systematic quantitative review.
Table 2.4. Studies looking at the acute effect of exercise on eating behaviours

<table>
<thead>
<tr>
<th>Author</th>
<th>Participants</th>
<th>Study design</th>
<th>Measurements</th>
<th>Intervention</th>
<th>Effects on food cravings or eating behaviours</th>
</tr>
</thead>
</table>
| Jankowski & Foss, 1972 | N=14 M  
Age=26.3  
BMI= 25.8 kg/m² | A within-subject design | Pre-weighed food | 440 yds and one mile running on a treadmill                                  | No differences between control and exercise conditions. Moderate exercise had no effect on the EI |
| Durrant et al., 1982 | N=16  
Obese: N=12,  
Age=27.0±10.0, BMI= 98.8±21.8 kg/m²  
Lean: N=4,  
Age=22.0±3.0, BMI= 21.8±2.1 kg/m² | A between-subject design  
2 conditions: exercise or non-exercise  
6 days (3 days of exercise and 3 days of rest) | Ad libitum food intake | Bicycle ergometer for 3 days to increase expenditure by 100 kcal/day          | During exercise, the obese ate less and the lean ate more (p < .03) |
| Reger et al., 1984 | N=11 NW F,  
Age=27±3,  
BMI=21.3±8 kg/m² | A within-subject design  
4 conditions: 3 exercise conditions (60 C, 30 C, 30 I) & a rest condition | Pre-weighed test meal, a 36hr food intake record, subjective rating (hunger & appetite) | 3 treadmill exercise conditions: 1) 60 C: continuous exercise at 50% VO₂ max for 60min; 2) 30 C: continuous exercise at 50% VO₂ max for 30min; 3) 30 I: 30 min of intermittent exercise 1min at 70% VO₂ max, alternating with 3min at 40% VO₂ max | No significant effect of exercise on food intake, but hunger rating was decreased immediately after 30I, compared to rest condition. Immediately after 30I and 30C, appetite ratings were significantly lower than the rest condition. However, there was a trend towards a decrease in total caloric consumption (48hrs following trials) in the 60C condition compared with the rest condition, and an increase after 30I condition. |
| Thompson et al., 1988 | N=16 M  
Age=23.8±3.9  
BMI= 22.5 kg/m² | A between-subject design  
3 conditions: low or high intensity exercise, control (sitting in a lounge area with light reading material) | Self-reported questionnaire, weighted test meal | Low-intensity (35% VO₂ max) and high-intensity (68% VO₂ max) cycle ergometer exercise | Hunger was suppressed in the high-intensity exercise condition (p < .05), while intake of liquid-source kilocalories and carbohydrates was higher after the exercise sessions ( p < .05) |
| Kissileff et al., 1990 | N=18 F  
9 non-obese: BMI=22.1 kg/m², age=22.7±4.9  
9 obese: BMI=27.7 kg/m², | A between-subject design  
3 conditions: strenuous or moderate exercise, rest | Self-reported questionnaire, a taste test, | Bicycle ergometer for 40 min at 60 rpm (90W for high-intensity, 30W for moderate) on non-consecutive days | Food intake was significantly reduced after the strenuous (p < .05) compared to moderate exercise or rest group, but not in the obese. The hunger ratings for obese subject after the moderate exercise was higher (p < .05) than after |
<table>
<thead>
<tr>
<th>Study Authors, Year</th>
<th>N</th>
<th>Age</th>
<th>BMI</th>
<th>Design</th>
<th>Meal</th>
<th>Exercise</th>
<th>Food Intake</th>
<th>Additional Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verger et al., 1994</td>
<td>N=58 M</td>
<td>25</td>
<td>21.3 kg/m²</td>
<td>A between-subject design</td>
<td>Ad libitum buffet meal</td>
<td>Either the strenuous exercise or rest</td>
<td>After exercise was larger than the meal consumed after no exercise (p &lt; .05)</td>
<td></td>
</tr>
<tr>
<td>Tremblay et al., 1994</td>
<td>N=9 M</td>
<td>28.3±6.1</td>
<td>24 kg/m²</td>
<td>A between-subject design</td>
<td>Pre-weighted food</td>
<td>Exercise or rest condition followed by low-fat diet, high-fat diet, and mixed diet</td>
<td>Increase in EI with exercise followed by high-fat, and a decrease in EI with exercise treatments followed by low-fat and mixed diets.</td>
<td></td>
</tr>
<tr>
<td>King et al., 1994</td>
<td>N=12 M</td>
<td>22 to 31</td>
<td>23.2 kg/m²</td>
<td></td>
<td></td>
<td>Food intake</td>
<td></td>
<td>No significant difference in EI between treatments</td>
</tr>
<tr>
<td>Almeras et al., 1995</td>
<td>N=11 M</td>
<td>24-36</td>
<td>24.4 kg/m²</td>
<td></td>
<td></td>
<td></td>
<td>A 90-min sub-maximal exercise bout on cycle ergometer</td>
<td>No effect of exercise on food intake.</td>
</tr>
<tr>
<td>King et al., 1996</td>
<td>N=13 unrestrained NW F</td>
<td>22.6±2.3</td>
<td>21.9±1.6</td>
<td></td>
<td></td>
<td></td>
<td>No significant effect of condition (exercise or rest), but post-hoc t tests showed that hunger was significantly lower during &amp; after exercise, compared with during &amp; after the rest condition.</td>
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</tbody>
</table>
Latency to eat was greater after exercise than rest. A significant effect of lunch type on total energy intake was shown, but exercise did not show a significant effect.

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>M</th>
<th>Age</th>
<th>BMI</th>
<th>Design</th>
<th>Food Intake</th>
<th>Interventions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Westerterp-Plantenga et al., 1997</td>
<td>30</td>
<td>M</td>
<td>25.0</td>
<td>22.8</td>
<td>A within-subject design 2 conditions: exercise and rest or sauna and rest (2h reading or studying while sitting) 2h of treatment for 8 times during 8 consecutive weeks (4 days for exercise or sauna, and 4 days for rest)</td>
<td>Ad libitum buffet-type food</td>
<td>A bicycle ergometer at 60% of VO₂ max</td>
<td>After exercise, hunger and EI were suppressed (p &lt; .01) compared to after the rest. Carbohydrate intake increased after the exercise and sauna (p &lt; .01)</td>
</tr>
<tr>
<td>King et al., 1997a</td>
<td>8</td>
<td>M</td>
<td>26.0±5.2</td>
<td>22.4</td>
<td>A within-subject design 2 conditions: exercise or rest (refrain from any exercise activities, but allow habitual activities) Two consecutive days</td>
<td>Food diary</td>
<td>Treadmill running at 70% Max HR for 50min</td>
<td>Average daily feeling of hunger on exercise day was significantly lower than non-exercise day (p &lt; .01). However, there was no significant effect of day or condition on EI.</td>
</tr>
<tr>
<td>Imbeault et al., 1997</td>
<td>11</td>
<td>M</td>
<td>24.4</td>
<td>23.2±2.3</td>
<td>A between-subject design 3 conditions: low or high intensity exercise or rest(sitting quietly and allowed to read or write)</td>
<td>Ad libitum buffet, hunger and fullness on VAS</td>
<td>Walking or running on a treadmill (low intensity=35% VO₂ max, energy expenditure of about 2050kJ, high intensity=75% VO₂ max energy expenditure of about 2050kJ)</td>
<td>No significant effect in post-exercise on EI. However, relative energy intake was lower after high intensity exercise compared with the control (p &lt; .001) and the low intensity exercise (p &lt; .05)</td>
</tr>
<tr>
<td>Lavin et al., 1998</td>
<td>16</td>
<td>M</td>
<td>22-30</td>
<td>21.3</td>
<td>3 conditions: two intensity of exercise (high/low), or rest condition</td>
<td>Ad libitum buffet-type food</td>
<td>30% VO₂ max for low intensity and 70% VO₂ max for high intensity exercise</td>
<td>EI was higher after both exercise sessions compared with rest</td>
</tr>
<tr>
<td>Gilsenan et al., 1998</td>
<td>7</td>
<td>M</td>
<td>37.0</td>
<td>21.1</td>
<td>A within-subject design 2 days study: 1d of exercise, 1d of no exercise</td>
<td>Ad libitum food intake</td>
<td>Three 40 min of cycle ergometer (75W)</td>
<td>No differences in EI</td>
</tr>
<tr>
<td>Lluch et al., 1998</td>
<td>12</td>
<td>F</td>
<td>21.7±2.2</td>
<td></td>
<td>A within-subject design A 2 (activity: rest or TFEQ, motivations to eat (hunger, High intensity exercise: cycling for 50 min at</td>
<td></td>
<td></td>
<td>No effect of exercise on EI, but there was a significant main &amp; interactive</td>
</tr>
<tr>
<td>Study</td>
<td>Participants</td>
<td>Design</td>
<td>Measures</td>
<td>Results</td>
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<tr>
<td>Lluch et al., 2000</td>
<td>N=25 (12 restrained eaters, 13 unrestrained eaters: split scores RS=10)</td>
<td>A between-subject design A 2 (exercise/rest) x2 (low/high fat lunch type)</td>
<td>Ad libitum lunch test meal for 30min, palatability, tastiness, &amp; pleasantness on VAS</td>
<td>High intensity cycling (70% VO$<em>2$$</em>{max}$) for 50 min</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>RE: age=21.7±2.2, BMI=22.6±1.9 kg/m$^2$</td>
<td></td>
<td></td>
<td>EI increased in both high-fat conditions compared with the low-fat (P &lt; .001). RE ate significantly more than NRE in the rest condition (t = 2.6, P &lt; .05; r = 0.54, P &lt; .01), but not in the exercise condition. After exercise, hedonic rating was increased (P &lt; .01), but no relationship between the rating and EI.</td>
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<tr>
<td></td>
<td>URE: age=22.6±2.3, BMI=21.9±1.6 kg/m$^2$</td>
<td></td>
<td></td>
<td>Moderate intensity exercise: walking on a treadmill for 1hr at 60% to 70% VO$<em>2$$</em>{max}$</td>
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<td>Visona &amp; George, 2002</td>
<td>N=36 OW F, Age=26±7, BMI=27±3 kg/m$^2$</td>
<td>A between-subject design Crossover study design 2 conditions: exercise and rest</td>
<td>TFEQ (create 3 groups: dieters with high restraint, D-HR; non-dieters with high restraint, ND-HR; non-dieters with low restraint, ND-LR), assessment of lunch EI and 12-hour EI</td>
<td>Appetite (hunger, desire to eat, prospective food consumption, fullness) and satiety on VAS, a buffet-style dinner, food related videotapes</td>
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<td>George &amp; Morganstein, 2003</td>
<td>N=24 F (12 NW: BMI 22±1 kg/m$^2$, 12 OW: BMI 28±1 kg/m$^2$), Age=35±8</td>
<td>A between-subject design 2 conditions: exercise or rest</td>
<td>Ad libitum lunch meal at the university cafeteria</td>
<td>Treadmill at moderate intensity (60% Max HR) for 1hr</td>
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<td>The overweight females consumed significantly more calories than the normal weight females in both conditions (P &lt; .02).</td>
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<td>Tsofliou et al., 2003</td>
<td>N=10 obese F, Age=50.0±8.5, BMI 37.2±6.5 kg/m$^2$</td>
<td>A within-subject design 3 conditions: moderate exercise, snack (served a snack and asked to consume it within 20min) &amp; rest (seat for 30min)</td>
<td>Appetite (hunger, desire to eat, prospective food consumption, fullness) and satiety on VAS, a buffet-style dinner, food related videotapes</td>
<td>Walk at a brisk pace for 20min</td>
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<td>Moore et al., 2004</td>
<td>N=19 girls, Age=10.0±0.6, BMI=18.5 kg/m$^2$</td>
<td>A within-subject design 3 conditions: low or high intensity exercise, sedentary activity</td>
<td>Self-reported questionnaire for appetite ratings, ad libitum energy</td>
<td>Cycle ergometers (low intensity exercise:50% or high intensity exercise: 75% of peak oxygen</td>
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<td>After exercise session, lunch energy was significantly less in the low-intensity exercise than in the sedentary condition (P &lt; .05).</td>
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<td>Study</td>
<td>N</td>
<td>Gender</td>
<td>Age (±SD)</td>
<td>BMI (±SD)</td>
<td>Design Description</td>
<td>Appetite</td>
<td>Exercise Condition</td>
<td>EI Results</td>
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<td>Pomerleau et al., 2004</td>
<td>31 F</td>
<td>Age 22.2±2.0, BMI 22.2±2.4 kg/m²</td>
<td>A within-subject design 3 conditions: low and high exercise, and rest</td>
<td>Appetite on VAS, ad libitum from buffet-type meal lunch, TFEQ</td>
<td>Equicaloric (350kcal) treadmill exercise (low intensity: 40% VO₂ max; high intensity: 70% VO₂ max)</td>
<td>EI was significantly greater after high intensity exercise than after rest, and low intensity condition was not different from the rest.</td>
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<td>Maraki et al., 2005</td>
<td>12 F</td>
<td>Age 28.0±6.4, BMI 19 to 25 kg/m²</td>
<td>A 2X2 repeated measures design 2 conditions: exercise or rest 2 time conditions: morning or evening</td>
<td>Self-reported questionnaire for appetite, a 24-hour diet record, VAS</td>
<td>One-hour aerobic and muscle conditioning exercise class</td>
<td>Although exercise trials produced an increase in appetite sensations, they did not alter EI and produced a decrease in relative energy intake.</td>
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<td>White et al., 2005</td>
<td>11 M</td>
<td>Age 25.6±5</td>
<td>A within-subject design 3 conditions: neutral, cold water temperatures, &amp; rest</td>
<td>Free access for 60 min to a standard buffet assortment of food items</td>
<td>A submersed cycle ergometer at 60% VO₂ max for 45 min in 33°C (neutral) and 20°C (cold) water temperatures</td>
<td>In the cold condition, EI was 44% and 41% higher than neutral and rest conditions, respectively (p &lt; .05).</td>
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<td>Broom et al., 2007</td>
<td>9 M</td>
<td>Age 21.2±0.7, BMI 22.2±0.7 kg/m²</td>
<td>A within-subject design 2 conditions: exercise or rest for 1hr</td>
<td>Hunger rating using a 16-point scale, a test meal for 15min 1hr treadmill run at 75% of VO₂ max</td>
<td>A main effect of time (p &lt; .0005) and a condition × time interaction effect for hunger (p &lt; .001). Area under the curve values for hunger were lower over the first 3hr of the exercise condition compared with the rest condition (p =.013)</td>
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<td>Burns et al., 2007</td>
<td>18</td>
<td>(9F: age 25.1±1.3, BMI 22.5±0.8 kg/m²; 9M: Age 24.5±1.3, BMI 23.4±1.0 kg/m²)</td>
<td>A within-subject design 2 conditions: exercise or rest for 1hr</td>
<td>Hunger scale on a 15-point visual scale, Blood samples at baseline, 0.5, 1, 1.5, 2, and 3hr after baseline One-hour treadmill run at 73.5% of VO₂ max</td>
<td>Hunger scores were suppressed during and after exercise, and it was significantly lower during exercise than rest condition. However, plasma total ghrelin concentration did not differ between conditions and no gender difference was found.</td>
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<td>Erdmann et al., 2007</td>
<td>7</td>
<td>(5F:2M), Age 24.4±0.6, BMI 21.4±0.8 kg/m²</td>
<td>A within-subject design 3 conditions: low intensity, high intensity exercise, and rest</td>
<td>Ratings of subjective hunger and satiety on VAS</td>
<td>Cycling for 30min Low intensity: a bicycle ergometer at 50W (60 rpm, EE 85.6 kcal); High intensity: 100W (60 rpm, EE 171.2 kcal)</td>
<td>Hunger and satiety rating were not significantly different between conditions at baseline, during exercise, and the postprandial period. Also, food and EI were not significantly different after both exercise conditions compared to the rest condition.</td>
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<td>Study 2 (duration)</td>
<td>N=7 (3F,4M), Age=24.8±0.7, BMI=21kg/m²</td>
<td>A within-subject design 4 conditions: exercise at 30, 60, 120 min, and rest</td>
<td>Ad libitum meal and a 120 min post prandial observation, ratings of subjective hunger and satiety on VAS</td>
<td>Cycling at 50W for 30 (85.6 kcal), 60 (171.2 kcal), 120 min (342.4kcal)</td>
<td>EI after 30min &amp; 60min exercise was not different from the control, but more food consumed after 120min exercise.</td>
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<td>Martins et al., 2007a</td>
<td>N=12 (6 F, 6 M), Age=25.9±4.6, BMI=23.7 kg/m², DEBQ: restrained=2.4±0.8, emotional=2.2±0.6, external=2.7±0.6</td>
<td>A between-subject design 2 conditions: exercise or rest (sitting quietly for 1hr)</td>
<td>a 24-hour diet record, VAS, ad libitum buffet</td>
<td>Cycling on a cycle ergometer at 65% of max HR for 60min</td>
<td>Absolute EI was higher in the exercise than control intervention (p &lt; .05), however, there was a significantly lower relative EI following the exercise period (p &lt; .05)</td>
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<tr>
<td>Martins et al., 2007b</td>
<td>N=29, Age=29.8±11.6, BMI=22.7 kg/m², DEBQ: restrained=2.4±0.7, emotional=2.5±0.7, external=3.0±0.5</td>
<td>A between-subject design 2 preload meals: high or low energy</td>
<td>ad libitum buffet, VAS, a 3day-food-diary, a daily exercise diary</td>
<td>A 6-week 30-45 min of moderate aerobic exercise program (4 times per week, 65-75% max HR)</td>
<td>At baseline there was no difference of EI between the two preloads. However, buffet EI after the high-energy preloads was significantly lower than after the LEP following the exercise intervention (p &lt; .01).</td>
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<td>Harris &amp; George, 2008</td>
<td>N=80 M, Total mean age=30 5 groups(each n=16): 1. NW, low-restraint, non-dieting (BMI= 22.0 kg/m²); 2. NW, HR, ND (BMI= 23.0 kg/m²); 3. OW, LR, ND(BMI= 27.0 kg/m²); 4. OW, HR, ND (BMI= 28.0 kg/m²); 5. OW, HR, dieting (BMI= 29.0 kg/m²)</td>
<td>A between-subject design A counterbalanced-crossover design on 2 days) 2 conditions: exercise and rest (sitting quietly for 60 min)</td>
<td>TFEQ, ad libitum lunch meal 15 min after completing experimental session, a 12-hour dietary recall by telephone</td>
<td>Walking on a treadmill for 1hr (60-65%Max HR)</td>
<td>There was no significant effect of exercise on post exercise EI either acutely or over 12hr. However, overweight dieters showed a significantly lower lunch and 12hr EI after exercise than overweight non-dieters.</td>
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<td>Taylor &amp; Oliver, 2009</td>
<td>N=25 (20 F, 5 M), Age=25.3±9.7, BMI=22.8 kg/m², FCQ-T=142.0±29.8</td>
<td>A within-subject design 2 conditions: exercise or passive (sitting quietly for 15 min)</td>
<td>The State/Trait Food Cravings Questionnaire (FCQ-S/T), Stroop word-colour interference task,</td>
<td>A 15 min semi-self-paced walk on a treadmill</td>
<td>An intense desire to eat was significantly reduced immediately after exercise (t= -2.5, p &lt; .05) and 10min post-exercise (t= -2.6, p &lt; .05)</td>
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<td>Study</td>
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<td>Finlayson et al., 2009</td>
<td>Within-subject</td>
<td>2 conditions: high intensity exercise or no exercise (involved being sedentary; reading or sitting quietly).</td>
<td>Visual analogue scales (VAS), visual food stimuli (computer procedure). The weighted ad libitum test meal</td>
<td>No difference between exercise and non-exercise condition for EI and appetite sensations.</td>
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<td>Stationary cycling at approximately 70% maximum heart rate for 50 min</td>
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<td>Bozinovski et al., 2009</td>
<td>Within-subject</td>
<td>4 conditions: 2 exercise or 2 rest for 15min (short-duration; SD) or 45min (long-duration; LD)</td>
<td>Motivation to eat (desire to eat, hungry, fullness, prospective food consumption) on VAS, <em>ad libitum</em> pizza lunch</td>
<td>SD exercise reduced the average appetite, desire to eat, and hunger (<em>p</em> &lt; .05) compared with SD rest. However, the subjective appetite was increased by LD exercise.</td>
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<td>Broom et al., 2009</td>
<td>Within-subject</td>
<td>3 conditions: resistance exercise, aerobic exercise, and rest</td>
<td>Test meals for 15min, ratings of perceived hunger (0 to 15)</td>
<td>Suppressed hunger during both aerobic and resistance exercise, compared with the rest condition. Aerobic exercise showed a greater suppression of hunger than resistance exercise at 0.75hr and 1hr.</td>
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<td>Schneider et al., 2009</td>
<td>Within-subject</td>
<td>2 conditions: active or sedentary (watched a 3min clip from a nature video) for 3 min</td>
<td>Taste test, Hunger on VAS, POMS, calorie intake by pre-weighed food</td>
<td>No difference between exercise and rest condition (<em>t</em>(61) = -0.46, <em>p</em> = .63). A significant condition × negative mood change interaction (<em>t</em>(57) = -2.49, <em>p</em> = .33), participants who reported increased negative mood during exercise consumed more calories in the exercise condition compared to the rest condition.</td>
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<td>King et al., 2010a</td>
<td>Within-subject</td>
<td>2 conditions: exercise and rest</td>
<td>Appetite (hunger, satisfaction, fullness &amp; prospective food consumption) on VAS, Energy intake by <em>ad libitum</em> buffet</td>
<td>There were differences in hunger and prospective food consumption between the exercise and rest condition (<em>p</em> &lt; .05) (suppressed hunger and prospective food consumption during exercise).</td>
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**Note:**
- EI: Energy Intake
- VAS: Visual Analogue Scales
- POMS: Profile of Mood States
| King et al., 2010b | N=14 M  
Age=21.9±0.5,  
BMI=23.4±0.6 kg/m² | A within-subject design  
2 conditions: exercise and rest | Appetite (hunger, satisfaction, fullness, & prospective food consumption) on VAS, *Ad libitum* buffet meals | Treadmill walking at subjectively paced brisk walking for 1hr | Exercise did not significantly influence appetite and EI (EI was not significantly different between the exercise and rest conditions). There was no compensation in EI for energy expended during walking. |

**Note.** EI – energy intake; VAS - Visual analogue scales; POMS – the Profile of Mood States; TFEQ – The Three-Factor Eating Questionnaire; M – males; F – females; NW – normal weight; OW – overweight. ND – non-dieting; HR - high-restraint; LR - low-restraint.
A total of 37 studies summarised by author, participants, study design, measurements used, types of exercise (e.g., exercise duration, intensity, and exercise types), and findings are shown. Among the studies, 5 studies showed an increase in energy intake/appetite, 21 studies showed a decrease, and 11 studies showed no changes. Eight studies compared different exercise intensities (Thompson et al., 1988; Kissileff et al., 1990; King et al., 1994; Imbeault et al., 1997; Lavin et al., 1998; Moore et al., 2004; Pomerleau et al., 2004; Erdmann et al., 2007) and 3 studies compared different exercise durations (King et al., 1994; Erdmann et al., 2007; Bozinovski et al., 2009). See Table 2.4 for the details.

In summary, exercise has variable acute effects on eating behaviours although review papers conclude that most evidence supports the idea that exercise does not induce an automatic increase in energy intake and hunger. It is also clear that the acute effects of exercise may be influenced or moderated by several factors such as subject characteristics (e.g., gender, age and BMI), and the different exercise characteristics (e.g., duration, intensity, type of exercise). The potential moderating effects of both subject and exercise characteristics will be considered next.

2.5.2. Subject characteristics

The effect of exercise on eating behaviour seems to be modulated by other factors such as gender, body weight, and eating characteristics (i.e., restrained eating). In a review paper, Hagobian and Braun (2010) propose a hypothetical model which suggests that gender differences may impact on the relationship between physical activity and energy regulation differently (see Figure 2.12).

![Hypothetical model of how physical activity impacts on hormonal and appetite regulation of energy balance in men and women](Source from Hagobian & Braun, 2010)
In the review, based on their earlier study (Hagobian, Sharoff, Stephens, Wade, Silva, & Chipkin, et al., 2009), this model (Figure 2.12) explains how gender differences may lead to different patterns of food intake after physical activity. With hormonal changes, exercise may increase food intake in women but have no effects in men, and in terms of appetite exercise may have no effects on food intake in women but decrease in men. In other words, women increase energy intake to partially compensate for energy expenditure due to exercise whereas men will have no change in energy intake. Similar results were shown in other studies (Stubbs et al., 2002a; 2002b; Imbeault, Saint-Pierre, Almeras, & Tremblay, 1997).

Body weight is also associated with variable energy intake after exercise. George and Morganstein (2003) found that normal weight females ate less food after exercise than no exercise condition whereas overweight females consumed more calories on both experimental days than normal weight females. There also was a weight-group difference in fat intake. Kissileff and colleagues (1990) examined the interaction effects of treatment × obesity level on food intake. They found that food intake was significantly lower after vigorous exercise than the other conditions in normal weight group, but not in the obese group.

Regarding eating behaviour typologies, Visona and George (2002) examined the role of dietary restraint and dieting status in post-exercise energy intake with three groups: high restraint, non-dieters with restraint, and non-dieters with low restraint. The dieters with high restraint and non-dieters with low restraint ate more on an exercise day than on a rest day, whereas the non-dieters with high restraint ate less on the exercise day than the rest day. Lluch, King, and Blundell (2000) found that unrestrained eaters increased energy intake after exercise but restrained eaters tended to decrease energy intake. Restrained eaters ate significantly more than unrestrained eaters in a rest condition. Similar to Visona and George’s study, Harris and George (2008) also examined the impact of body weight, dietary restraint, and dieting status (dieter/non-dieter) on energy intake after moderate exercise. They did not find any differences between overweight and normal weight males in energy intake following exercise. However, there were diet status differences of in energy intake among the overweight males. Overweight dieters showed a significantly lower lunch and 12hr energy intake after exercise than overweight non-dieters.

In general, several factors have appeared to influence energy intake and appetite following an exercise session. The studies mentioned indicate that for some people exercise alone seems to be an effective method of regulating food intake, but for others the effects are less certain. Apart from subject characteristics, exercise characteristics may also have an important effect on energy intake and appetite following exercise.
2.5.3. Exercise characteristics

Various types, durations, and intensities of exercise have been used in studies on the effect of exercise on the regulation of food intake. Several different types of aerobic exercise have all been shown to have a regulating effect on appetite: 15 min semi-self-paced brisk walk (Taylor & Oliver, 2009), 60 min brisk walking (King, Wasse, Broom, & Stensel, 2010b), 50 min running (King, Lluch, Stubbs, & Blundell, 1997a), and cycle ergometers (Moore et al., 2004; Westerterp-Plantenga, Verwegen, Ijedema, Wijckmans, & Saris, 1997; Kissileff, Pi-Sunyer, Segal, Melzter, & Foelsch, 1990).

Duration. Only a few studies have examined the effect of different durations (i.e. comparing short and long duration). In a children study, Bozinovski and colleagues (2009) assessed the effect on appetite of different durations of moderate treadmill exercise at the ventilation threshold (15 min for short duration and 45 min for long duration exercise). They found an attenuating effect of short duration of exercise on average appetite, desire to eat and hunger, compared with the resting condition. On the other hand, a longer duration of exercise increased average appetite, desire to eat, and hunger, compared with the resting condition. However, food intake after both durations of exercise was similar to after the rest condition. Their findings suggest that short duration of exercise may be an effective way to control food intake. In an early study (Reger, Allison, & Kurucz, 1984), the short-term appetite suppressant effect was shown after 30 min of continuous and intermittent treadmill exercise, relative to the rest condition. King, Burley, and Blundell (1994), in their 2nd study, found that subjective hunger was suppressed during both short and long duration exercise session whereas the suppression in hunger was greater after a longer duration (52 min) of high intensity exercise than short duration (26 min) and rest. In contrast, Erdmann and colleagues (2007) compared the effect of different durations of cycling at 50W on energy intake: for 30, 60, and 120 min. Energy intake after the 30min and 60min exercise was not different from the control condition, but food intake after a longer duration (120min) of cycling was significantly greater compared to the other conditions.

Intensity. Review papers (Blundell et al., 2003; Blundell & King, 1999; King 1998; King et al., 1997b) state that short-term vigorous exercise leads to the reduction in hunger called ‘exercise-induced anorexia’. However this is short-lived and is not seen with low or moderate intensity exercise. Thompson, Wolfe, and Eikelboom (1988) and Kissileff and colleagues (1990) also showed briefly suppressed hunger ratings following high intensity exercise were lower than following low intensity exercise and a rest condition, through the effect lasted for only a short duration. King and colleagues (1994) found that subjective hunger was suppressed during and after high intensity exercise (70% VO2 max), but the suppression was short-lived (within 15mins). Low intensity exercise (30% VO2 max) did not produce any suppression of hunger either during
or after the session. In contrast, a children study (Moore et al., 2004) found that low intensity exercise (cycling at 50% of peak oxygen uptake, 1.50MJ energy expenditure, EE) caused less lunch energy intake than high intensity exercise (75% of peak oxygen uptake, 1.50MJ EE). Moreover, energy difference (*ad libitum* energy intake - EE) was significantly greater in the rest condition, and was slightly greater in the high intensity condition than for low intensity exercise. Pomerleau and colleagues (2004) compared low intensity (40% VO$_2$$_{max}$) and high intensity (70% VO$_2$$_{max}$). More energy was ingested at lunch time after the high intensity exercise session than after the control session whereas relative energy intake at lunch was lower after both intensity exercise sessions compared with after the control session. Erdmann and colleagues (2007) did not find any difference between low intensity (50W) and high intensity exercise (100W) compared to a control condition.

The relationship between exercise and food intake is complex: both physiological and psychological variables (e.g., cravings, attentional bias) can help to improve our understanding of the relationship. The evidence mentioned above has focused on changes in energy intake following exercise rather than food cravings and hedonic hunger. Little is known about the effect of exercise on food craving. As food cravings are regarded as a symptom of addiction (Avena et al., 2008), the effect of exercise on food craving may be different from the findings of energy intake studies. No studies compared the intensity of exercise on food cravings, but two moderate exercise studies (Thayer et al, 1993; Taylor & Oliver, 2009) have examined the effect of acute exercise on food craving. In the earlier study, Thayer and colleagues (1993) focused on the effect of exercise on mood and other addictive behaviours (i.e., smoking and sugar snacking). Eighteen sugar snackers were instructed to undertake either a 5 min brisk walk or sedentary activity (e.g., reading, TV watching), and were asked to rate urge-to snack before and after treatments. Then, they were instructed to note the time of eating the next snack. They found that a 5 min brisk walk significantly decreased the urge to snack and lengthened the time until eating the next snack compared to an inactive condition. Taylor and Oliver (2009) built on this study by adding manipulation of baseline food craving and food cues. Twenty-five regular chocolate eaters, abstaining from chocolate for 3 days, were randomly assigned to a 15 min brisk walk or rest condition (i.e., sitting quietly) on separate days. Following the 15 min sessions (the treatment), they were engaged in a mental challenge task for stress reactivity, and subsequently asked to select and open a wrapped chocolate bar. They reported that food craving was significantly lower immediately after the exercise condition and 10 mins post-treatment, and there was a trend towards attenuated urges in response to the chocolate cue.

Both of the above studies showed that exercise reduced the urge for a certain type of food (e.g., chocolate). Thayer and colleagues (1993) also assessed momentary mood state while measuring the urge to snack. They found an increase in subjective energy and a reduction in subjective...
tension following exercise. Taylor and Oliver (2009) measured affective valence and activation, and positive changes were shown following exercise. Exercise induced affect changes may have an impact on self-regulation of food craving. Thus, in the following section, the possible mechanisms will be reviewed to explore how exercise may have an influence on food craving.

2.5.4. Mechanism

Exercise induced changes in food craving may be mediated through affect, expectancy, and distraction. Each of these possible mechanisms will be explored below.

Positive-activated affect. As mentioned in the earlier section, craving for certain foods and their consumption are related to strategies for mood regulation (Thayer, 1987), and, like foods, exercise can also be considered as a commonly used mood regulator (Thayer et al., 1994, Thayer, 2001). Given their shared relationship in mood regulation, the effect of exercise on food craving may be mediated by exercise induced affect changes. Reed and Buck (2009), in a meta-analysis, examined the effect of regular aerobic exercise on positive-activated affect, which is one dimension of the affect circumplex model (Russell, 1980). They found the exercise increased positive-activated affect, especially for low-moderate intensity exercise (30-35min, 3-5 days/wk for 10-12 weeks). Affect changes from pre- to post-exercise have been examined in several papers by Ekkekakis (Ekkekakis, Parfitt, & Petruzzello, 2011; Ekkekakis, Hall, & Petruzzello, 2008; Ekkekakis & Acevedo, 2006; Ekkekakis, Hall, Van Landuyt, & Petruzzello, 2000). Most of these studies have reported the positive affective changes during and after self-paced low-moderate intensity exercise. In line with these studies, Taylor, Katomeri, and Ussher (2006) found that a self-paced 1 mile walk significantly reduced tension, increased affective valence at the end of exercise, and increased activation during and up to 20 min post-exercise, compared with the control condition (see Figure 2.13).

The importance of mood change to exercise and energy intake was shown in a study by Schneider and colleagues (2009). Sixty-five overweight sedentary subjects took part in a 3 min moderate exercise (i.e., step test) and sedentary activity, in counterbalanced order, and energy intake was assessed by pre-weighed snack food. Moderation analyses showed that negative mood change from pre- to post-exercise was positively related with the consumed calories from pre-weighed snack food. The generalisability of this finding may be limited as the exercise bout involved an unfamiliar exercise in the form of a step test which led to an increase in negative affect.
**Figure 2.13.** Responses to valence (the feeling scale, FS) and activation (activation scale, FAS) (Source from Taylor et al, 2006)

*Expectation about the effect of exercise.* The second possible mechanism is that expectation of the effects of exercise on food cravings (e.g., exercise reduces food craving) may be related to the actual reduction in desire for snacking after exercise. Outcome expectancy, which is closely related to self-efficacy (Janzen, Silvius, Jacobs, Slaughter, Dalziel, & Drummond, 2006), has been regarded as an important predictor of behaviour and has been used to predict specific behaviours such as relapse in ex-smokers (Dijkstra & Borland, 2003), alcohol consumption (see a review paper, Jones, Corbin, & Fromme, 2001), eating disorders (Hohlstein, Smith, & Atlas, 1998) and physical activity (Heinrich, Maddock, & Bauman, 2011). Hohlstein and colleagues (1998) state that beliefs or expectancies have behavioural consequences and influence individuals’ behavioural choices. They applied expectancy theory to eating disorders and found that expectancies for negative reinforcement from eating (e.g., eating helps manage negative affect) were related to bulimic, but not anorexic, individuals.

Two experimental studies have examined the effect of expectation about exercise on psychological well-being and desire to smoke. Desharnais, Jobin, Cote, Levesque, and Godin (1993) examined the placebo effect of exercise on psychological well-being. Participants were engaged in a 10-week exercise programme and randomly assigned to one of two conditions: experimental condition (expectancy manipulation: providing information about the psychological benefits of exercise) and control condition (no intervention). They found that a significantly improved self-esteem over time was shown in the experimental condition compared with the control condition. On the other hand, only one study, Daniel, Cropley, and Fife-Schaw (2007) investigated whether participant expectation of exercise is related to a reduction in desire to smoke and smoking withdrawal symptoms. Sedentary, temporarily
abstained smokers were randomly assigned to one of three groups each of which issued with a statement of expectation of exercise on smoking withdrawal symptoms: positive, negative, or neutral. Participants read the statement and rated their expectation. They then completed 10 min of moderate intensity exercise (40-60% HRR). Their desire to smoke and smoking withdrawal symptoms were measured from 10 min before exercise to 20 min post-exercise at 5 min intervals. Although the expectations were successfully manipulated before taking part in exercise, there were no group effect on desire to smoke and withdrawal symptoms during and after 10 min of exercise. In other word, the exercise induced reductions in desire to smoke and smoking withdrawal symptoms were not due to the expectation of exercise effect. Thus, there is no evidence to suggest that expectation may be related to reduction in food cravings.

Distraction. The last issue is that exercise could operate as a distraction from food-related thoughts, compared with a resting condition. Only one study, Daniel, Cropley, and Fife-Schaw (2006) has examined if the reduction of desire to smoke and cigarette withdrawal symptoms following moderate exercise was caused by distraction. Temporarily abstained smokers were randomly assigned to one of two conditions: 10 min moderate intensity exercise or 10 min cognitive distraction task (a paced visual serial addition task, which required participants to watch the presentation of single digit numbers presented one per second). Their desire to smoke and smoking withdrawal symptoms were measured from 10 min before exercise to 20 min post-exercise at 5 min. intervals. They found that there were significant decreases in desire to smoke and withdrawal symptoms during and immediately following exercise; however the cognitive distraction task did not lead to reductions in ratings. The findings suggest that cognitive distraction during exercise is not the main mechanism producing changes in cravings.

To sum up, evidence suggests that various factors may have an influence on the relationship between exercise and eating behaviours (including energy intake, attentional bias to food cues, and food cravings) and the mechanisms are uncertain. There is unexplained variability in how people respond to exercise in terms of hunger and food intake. Some studies have shown a positive effect and some studies have shown a negative effect or no effect. However, no studies have looked at people who are just regular snackers who are therefore more likely to find it difficult to self-regulate when they are faced with cues during deprivation when they are likely to have higher cravings. Also, there has been a lack of research on the relationship between a lower intensity and short bouts of physical activity and self-regulation of snacking.

The following chapters (Chapter 3-5) will report on three studies to examine the relationship between a short bout of exercise and self-regulation of snacking among regular chocolate eaters using various outcome measures.
Chapter 3. Study 1
Effects of brisk walking on ad libitum snacking in regular chocolate eaters
during a workplace simulation

3.1. Introduction

Eating behaviour is a complex phenomenon and influenced by several factors such as psychological (i.e., mood, stress), physiological (i.e., hunger), and environmental factors (i.e., food cues, social events). Thayer (2001) explained an over eating mechanism in which certain individuals eat to cope with stress, and regulate mood, and are therefore at risk to become obese. Based on Emotional Eating Theory, Thayer (2001) noted that negative mood such as depression, anxiety, boredom, and loneliness are associated with low energy and increased tension. People try to change or self-regulate these negative states with food and thus they tend to increase energy intake. Others have also reported that stress has a detrimental effect on health behaviour such as food choice and appetite (Gibson, 2006; Oliver, Wardle, & Gibson, 2000; Oliver & Wardle, 1999; Greeno & Wing, 1994). Stress is linked to health risk factors in both direct (i.e., cardiovascular disease), and indirect ways. For example, people learn to cope with stress by using unhealthy behaviours such as a higher fat diet, smoking and less frequent exercise (Ng & Jeffery, 2003).

Three types of research links stress to eating: epidemiological surveys (Sims et al., 2008; Oliver & Wardle, 1999; Spillman, 1990), in-situ experiential sampling studies (Weidner et al., 1996), and laboratory-based experimental manipulation studies (Tanofsky-Kraff et al., 2000; Heatherton, Herman, & Polivy, 1991a). Among the research, in experimental studies that have investigated the relationship between stress and eating behaviour (Gluck, 2006; Johansson, Ghaderi, & Andersson, 2004), food intake, following laboratory stressors, increased more than after non-stress conditions. Stress may lead people to eat more and may result in seeking comfort foods or foods that elevate mood, and most of these foods are relatively high in fat and salt or sugar. Many studies of the effect of stress on food choice have found that people tend to increase their consumption of highly calorific sweet and fatty snack foods when stressed (Cartwright et al., 2003; Wardle et al., 2000; Baum & Posluszny, 1999). Also, stress produces differential effects on eating depending on the type of consumer. Restrained eaters (those who intentionally control or restrict food intake to maintain or lose weight) and emotional eaters (those who overeat in response to negative emotional arousal)
have been found to consume more energy and fat under-stressful conditions (Heatherton, Herman, & Polivy, 1991a, 1992; Oliver et al., 2000).

Chocolate is the most commonly craved food and it has a comforting effect that temporarily enhances our mood (Radin et al., 2007; Macht & Dettmer, 2006). However, the excessive consumption of it is an unhealthy behaviour related to the weight gain. Saturated fat, which is high in many food sources such as chocolate, is associated with increased blood cholesterol concentrations and an increased risk of heart disease (Hu, Stampfer, Manson, Rimm, Colditz, Rosner et al., 1997). Blundell, Cooling, and King (2002) stated that the excessive intake of fat is a major risk factor for obesity because fat is the least satiating of all nutrients, is oxidized least preferentially, and the body has an unlimited storage capacity for it. Previous experimental studies increased cravings or urges to eat specific food by manipulating abstinence (Polivy et al., 2005), stress or negative mood (Taylor & Oliver, 2009; Parker & Crawford, 2007), and exposure to food cues (Tiggemann & Kemps, 2005; Fedoroff et al., 2003; Jansen, Theunissen, Slechten, Nederkoorn, Boon, & Mulkins et al., 2003; Tuomisto et al., 1999). For example, after exposure to food cues (smell), restrained eaters are more responsive to the cues and significantly ate more (Fedoroff et al., 2003).

People under emotional distress (e.g., sad and distressed mood) eat more unhealthy foods because they expect that the palatable food will make them feel better (Tice et al., 2001). Also, boredom, feeling fatigued, and deactivation are common states which are associated with stress, and people engage in eating behaviours to deal with these emotional states (Abramson & Stinson, 1977). Most studies were based on the effect of stress or negative mood on eating behaviours and few examined the moderating effects of exercise on food craving and high energy food snack consumption such as chocolate. With self-regulation of mood, Thayer (1987; 1994) explains the tendency of people to regulate their moods to comfortable levels and how exercise can replace other mood regulators (e.g., smoking, snacking) for this. The results of his studies suggest that even short bouts of moderate intensity physical activity (e.g., walking) has the potential to influence affect, and hence smoking and snacking.

Some studies have examined the relationship between exercise and energy intake with ad libitum access to food to create a natural situation in a laboratory setting (Martins, Morgan, Bloom, Robertson, 2007a, Martins, Truby, & Morhan 2007b; Moore et al., 2004). However, under these conditions energy intake may not be entirely ad libitum and more studies are needed to examine ad libitum intake environments, which are similar to reality, without telling people to eat. Most of the studies have investigated the effects of exercise on appetite and energy intake with high intensity or longer duration exercise, and only a few studies have
considered the acute effect of moderate intensity exercise such as brisk walking (Taylor & Oliver, 2009, Thayer et al., 1993). Given that higher doses of exercise are avoided by many people with weight concerns there is a need to understand the effect of moderate intensity exercise versus passive behaviour which may stimulate quite different affective responses.

There is evidence that exercise has a positive effect on psychological well-being including positive activated affect (Reed & Ones, 2006; Ekkekakis & Acevedo, 2006), mood (Maraki et al., 2005; Lane & Lovejoy, 2001), and stress (Taylor, 2000; Thayer, 1987). Thayer (1987) suggested that a rapid 10-min walk is associated with higher self-rated energy and lower tension, and it could be a replacement of a sugar snack for regulating mood. Exercise is an intervention which could reduce negative effects of stress and stress related blood pressure (Hamer, Taylor, & Steptoes, 2006; Taylor & Katomeri, 2006). Taylor (2000) concluded, in a review, acute exercise could reduce psychophysiological reactivity to psychosocial stressors. A number of studies have considered the acute effect of exercise on appetite and eating behaviour, and stress, but only one study has examined the effects of exercise on food craving during explicitly manipulated stress (Taylor & Oliver, 2009). Taylor & Oliver (2009) did not find any effect of exercise in moderating stress-induced chocolate cravings, but they did not measure actual eating behaviour. Although previous research into the link between exercise and stress, and stress and eating behaviour is extensive, no study has examined the relation between exercise and high caloric food consumption in response to a high and low stressor. One may expect that high stress leads to greater eating than when under low stress, and exercise reduces eating, particularly in the high stress condition.

Thus, the purpose of the present study was to examine if manipulated stress is associated with increased chocolate consumption, and if a short bout of exercise moderates this effect. Also, the aim was to determine if the changes in affect from pre-post exercise mediated any effects of exercise on chocolate consumption. Lastly, an aim was to explore if participant’s tendency to be emotional or restrained eaters impacted on any effect of exercise.

3.2. Methodology

3.2.1. Participants

Participants were recruited through public messages (posted on walls and through email communication) or were given a flyer in public settings. The initial selection criterion for
inclusion in the study was that participants had to eat at least 100g of chocolate (or 2 chocolate bars) per day. Also, they were asked three questions: 1) “how would you describe the experience of eating chocolate?”, 2) “How often do you have cravings for sweets?”, 3) “How often do you have cravings for chocolate?” using a 6-point scale (1 = very unpleasant/strongly disagree, 6 = very pleasant/strongly agree). The individual scores of these three questions were added up to provide a total score, with total scores ranging from 3 to 18. The selecting standard of chocolate craving was from 12 to 18. A total of 78 volunteers (33 males, 45 females), with mean age (SD) of 24.90 (8.15) years and a mean body mass index (BMI) (SD) of 23.56 (3.78), took part in a between-subject, randomised study.

3.2.2. Procedures

The experimental protocol was approved by the University of Exeter Ethical Committee and subjects gave written informed consent and information sheet (see Appendix 1). Participants initially completed a 3 day diary of chocolate consumption. Following that, they were asked not to eat chocolate for 2 days. They were then asked to refrain from food and drink (excluding water) for 3 hours before coming into the laboratory. Upon arrival at the laboratory, participants were introduced to the overall protocol, and provided data on height and weight and wore a heart rate (HR) monitor throughout the session to identify cardiovascular response to the treatment and tasks. HR was measured each 15 sec.

Participants were randomly assigned to one of four conditions, in a 2 x 2 factorial design. The four experimental conditions were thus: 1) exercise and high-stress condition; 2) exercise and low-stress condition; 3) no exercise and high-stress condition; 4) no exercise and low-stress condition.

Exercise treatment: A self-paced bout of exercise was employed in the experimental condition. The exercise session consisted of a 2 minute warm-up, followed by a 15 minute brisk walk (semi-self-paced) on a flat motorised treadmill. A variety of measures were used to monitor the participants’ exercise intensity, including heart rate and Rating of Perceived Exertion (RPE, Borg, 1998), using a scale ranging from 6 (very, very light) to 19 (very, very hard). Participants were instructed to work at a level between 11 (fairly light) and 13 (somewhat hard) ‘as if late for a bus or appointment, but not to the point of breathlessness.’
Passive treatment: Participants were required to sit passively and quietly at a desk for 15 minutes with no reading materials.

After completing a 15 mins treatment session, participants sat quietly at a computer terminal for 5 mins before engaging in a cognitive challenge task which attempted to simulate a work place.

Cognitive challenge. The Stroop Colour-Word Interference Task (Stroop, 1935) was used as a stressor, following previous evidence that it typically serves to increase cardiovascular stress. It consisted of the three colour names printed in incongruent colours. In the centre of the monitor, one coloured word was shown and participants were asked to respond to the character of the word while ignoring the colour of the word (see Appendix 2). From the keyboard, V corresponds to choice on the left, B corresponds to choice on the middle, N corresponds to choice on the right. They were asked to answer as quickly as possible while trying to avoid making errors. They were required to do a Stroop colour-word interference task under low and high-stress conditions. This was determined by the pacing of the stimuli presented (i.e., a 1 sec inter-stimulus interval for high, and 4 sec inter-stimulus interval for low stress). Each block of Stroop trials lasted 180 sec and three blocks were separated by a 90 sec rest period, adding up to a total of 720 sec. The number of mistakes and reaction time were recorded using E-prime (version 1.2). The perceived task demand was self-reported (0 = not at all demanding, 6 = very demanding), at the end of the experiment.

After the Stroop tasks chocolate cravings were assessed before and after opening a personally selected wrapped chocolate bar from several types of chocolates of similar individual weight, to increase the likelihood of participants increasing their cravings. At the end of the experiment the general characteristics of the sample were obtained using self-report questionnaires.

3.2.3. Measures

The overall time points of measures are shown in Figure 3.1.

Ad libitum chocolate consumption. Throughout the session, on the table besides the computerised Stroop task, a bowl of loose and unwrapped chocolate (i.e., ‘Buttons’, and dark and white ‘Maltesers’) was available. Participants were informed that they could help
themselves to as many as they wished. The chocolate bowl was weighed prior to, and again after participants had left.

**Figure 3.1.** The time points of measure

*Chocolate Craving.* The State Food Craving Questionnaire (FCQ-S, Cepeda-Benito et al., 2000b), adapted for chocolate by Rodriguez, Fernandez, Cepeda-Benito, & Vila (2005) and Rodriguez, Warren, Moreno, Cepeda-Benito, & Gleaves (2007), was administered to assess chocolate cravings after the Stroop task and opening a chocolate bar as shown in Figure 3.1. The FCQ-S (15 items) measures the intensity of five state dimensions (each 3 items) of food cravings, including: (1) an intense desire to consume food; (2) anticipation of positive reinforcement that may result from eating; (3) anticipation of relief from negative states and feelings as a result of eating; (4) possible lack of control over eating if food is eaten; (5) craving as a hunger/physiological state. Responses were made on a 5-point Likert scale (1 = *Strongly disagree*, 5 = *Strongly agree*).

*Affect.* The 11-point (from -5 to +5; low to high feeling of pleasure) Feeling Scale (Hardy & Rejeski, 1989) and the 6-point (from 1 to 6; low to high feeling of activation/arousal) Felt Arousal Scale (Svebak & Murgatroyd, 1985) were assessed to measure affective valence and activation throughout the study as shown in Figure 3.1 at seven time-points: (1) at baseline, (2) mid-treatment, (3) post-treatment, (4) after 1st task, (5) after 2nd task, (6) after 3rd task, (7) after opening a chocolate bar.

*General eating characteristics.* The Emotional Eating Survey (from the Trait Food Craving Questionnaire, FCQ-T, 12 items) measures (1) anticipation of positive reinforcement that may result from eating; (2) anticipation of relief from negative states and feelings as a result of eating; (3) Emotions that may be experienced before or during food craving or eating, with a 6-point Likert scale (1 = *Never*, 6 = *Always*). The Restrained and Emotional Eating subscales of the DEBQ (Van Strien et al., 1986a) were used to measure beliefs about eating; they consist of 10 items and 13 items, respectively, and have a 5-point scale ranging from *never* to
very often. A score for both restrained and emotional eating were obtained by summing the scores for the respective items. A higher score indicates greater dietary restraint and a tendency to be an emotional eater. Questionnaires used are shown in Appendix 3.

3.2.4. Statistical analysis

For all statistical analyses, SPSS (version 15) was used. Initially, a one-way ANOVA was carried out to compare baseline measures between groups and to check difference in HR, FS, FAS, perceived task demand and errors between exercise and rest. Total chocolate consumption as an outcome was analysed using a two-way ANOVA to examine the main and interaction effects of treatment (exercise and rest) and task (low and high stress). Also, the analysis was repeated with general eating characteristics (i.e., FCQ-T & DEBQ) as covariates to control for the effects of them. As suggested by Cerin (2010) and Baron and Kenny (1986), mediation analysis was conducted to determine if changes in affect from pre- to post- exercise mediated any effects of exercise on chocolate consumption. The significance was set at $p < .05$ for all statistical tests and Mauchly’s test of Sphericity was applied to all ANOVAs, and Greenhouse-Geisser correction technique was applied where appropriate.

3.3. Results

3.3.1. Participant Demographics

The general characteristics of participants are shown in Table 3.1. ANOVA’s revealed no significant differences between the four conditions for the participant’s mean (SD) values for age, BMI, FCQ-T and DEBQ.

Table 3.2 shows baseline scores for mean (SD) values for HR, FS, and FAS for each condition, throughout the experiment.
<table>
<thead>
<tr>
<th>Variable</th>
<th>1 (n=20)</th>
<th>2 (n=19)</th>
<th>3 (n=20)</th>
<th>4 (n=19)</th>
<th>All participants (n=78)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>25.85(9.25)</td>
<td>23.47(6.35)</td>
<td>24.85(8.23)</td>
<td>25.37(8.88)</td>
<td>24.90(8.15)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.5(3.7)</td>
<td>23.9(4.6)</td>
<td>23.2(4.2)</td>
<td>23.6(2.6)</td>
<td>23.56(3.77)</td>
</tr>
<tr>
<td>FCQ-T Dimension 1</td>
<td>19.75(5.57)</td>
<td>18.42(7.07)</td>
<td>18.00(5.34)</td>
<td>18.05(7.04)</td>
<td>18.56(6.20)</td>
</tr>
<tr>
<td>FCQ-T Dimension 2</td>
<td>10.25(3.86)</td>
<td>9.63(4.79)</td>
<td>9.90(3.63)</td>
<td>9.37(3.92)</td>
<td>9.79(4.00)</td>
</tr>
<tr>
<td>FCQ-T Dimension 3</td>
<td>16.30(5.61)</td>
<td>14.37(5.97)</td>
<td>15.20(5.56)</td>
<td>15.74(6.51)</td>
<td>15.41(5.84)</td>
</tr>
<tr>
<td>DEBQ (RE) Total Mean(SD)</td>
<td>23.55(8.92)</td>
<td>22.37(9.34)</td>
<td>27.25(8.12)</td>
<td>24.37(8.21)</td>
<td>24.41(8.68)</td>
</tr>
<tr>
<td>DEBQ (RE) Mean item score(SD)</td>
<td>2.35(0.89)</td>
<td>2.24(0.93)</td>
<td>2.73(0.81)</td>
<td>2.44(0.82)</td>
<td>2.44(0.87)</td>
</tr>
<tr>
<td>DEBQ (EE) Total Mean(SD)</td>
<td>40.45(12.66)</td>
<td>37.42(12.21)</td>
<td>39.90(11.77)</td>
<td>39.79(13.76)</td>
<td>39.41(12.42)</td>
</tr>
<tr>
<td>DEBQ (EE) Mean item score(SD)</td>
<td>3.11(0.97)</td>
<td>2.88(0.94)</td>
<td>3.07(0.91)</td>
<td>3.06(1.06)</td>
<td>3.03(0.96)</td>
</tr>
</tbody>
</table>

Notes: Condition 1: exercise-high stress; Condition 2: exercise-low stress; Condition 3: rest-high stress; Condition 4: rest-low stress. FCQ-T. Dimension 1: anticipation of positive reinforcement that may result from eating; Dimension 2: anticipation of relief from negative states and feelings as a result of eating; Dimension 3: emotions that may be experienced before or during food craving or eating. DEBQ. Restraint eating (RE): Total mean (SD) score; Mean item score for 10-items. Emotional eating (EE): Total mean (SD) score; Mean item score for 13-items.
Table 3.2. Mean (SD) scores for heart rate, Feelings Scale, and Felt Arousal Scale, by condition, over time

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Task</th>
<th>Variable</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
<th>T7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
<td>High</td>
<td>HR</td>
<td>77.01</td>
<td>115.81 (12.12)</td>
<td>84.60 (10.44)</td>
<td>80.87</td>
<td>79.12 (7.91)</td>
<td>77.68</td>
<td>78.16 (8.93)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS</td>
<td>2.45 (2.21)</td>
<td>2.45 (1.64)</td>
<td>2.95 (1.64)</td>
<td>1.30</td>
<td>1.85 (2.13)</td>
<td>2.10</td>
<td>2.80 (1.64)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FAS</td>
<td>3.90 (0.97)</td>
<td>4.10 (0.72)</td>
<td>4.10 (1.12)</td>
<td>4.10</td>
<td>4.05 (1.10)</td>
<td>4.05</td>
<td>4.25 (0.97)</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>HR</td>
<td>89.98 (18.99)</td>
<td>116.90 (13.91)</td>
<td>87.28 (12.45)</td>
<td>82.80</td>
<td>80.00 (12.11)</td>
<td>77.25</td>
<td>79.32 (12.45)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS</td>
<td>2.62 (1.61)</td>
<td>2.63 (1.12)</td>
<td>2.95 (1.03)</td>
<td>3.26</td>
<td>3.05 (1.27)</td>
<td>2.95</td>
<td>3.58 (1.07)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FAS</td>
<td>4.16 (1.39)</td>
<td>4.53 (1.02)</td>
<td>4.68 (0.82)</td>
<td>4.21</td>
<td>4.11 (1.41)</td>
<td>3.74</td>
<td>4.26 (1.33)</td>
</tr>
<tr>
<td>Rest</td>
<td>High</td>
<td>HR</td>
<td>77.89 (12.79)</td>
<td>75.10 (12.29)</td>
<td>78.42 (13.23)</td>
<td>81.54</td>
<td>79.89 (11.66)</td>
<td>78.38</td>
<td>79.41 (10.29)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS</td>
<td>2.15 (1.60)</td>
<td>2.20 (1.40)</td>
<td>1.95 (1.79)</td>
<td>1.65</td>
<td>1.60 (2.39)</td>
<td>2.00</td>
<td>2.65 (2.01)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FAS</td>
<td>2.90 (1.41)</td>
<td>2.45 (1.47)</td>
<td>2.55 (1.67)</td>
<td>3.25</td>
<td>3.55 (1.36)</td>
<td>3.70</td>
<td>3.50 (1.47)</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>HR</td>
<td>75.36 (10.41)</td>
<td>71.20 (11.72)</td>
<td>72.29 (9.56)</td>
<td>77.41</td>
<td>78.30 (10.87)</td>
<td>77.49</td>
<td>76.05 (10.11)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS</td>
<td>2.68 (1.25)</td>
<td>2.47 (1.35)</td>
<td>1.89 (1.66)</td>
<td>2.84</td>
<td>3.00 (1.16)</td>
<td>2.95</td>
<td>3.37 (1.21)</td>
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<tr>
<td></td>
<td></td>
<td>FAS</td>
<td>3.47 (1.12)</td>
<td>3.00 (1.05)</td>
<td>2.53 (1.26)</td>
<td>3.68</td>
<td>3.47 (1.22)</td>
<td>3.32</td>
<td>3.84 (1.30)</td>
</tr>
</tbody>
</table>

Notes: Time line. T1: baseline; T2: mid-treatment; T3: post-treatment; T4: after 1st task block; T5: after 2nd task block; T6: after 3rd task block; T7: after opening a chocolate bar.
3.3.2. Manipulation checks

**Exercise effects**

The mean heart rate (HR) during exercise and rest conditions was 116.35 (12.88) bpm and 73.20 (12.02) bpm, respectively, and the mean self-selected intensity of exercise (in terms of HR reserve, HRR) was 28.75% (14.79). Not surprisingly, analysis of HR indicated a significant interaction of time (3 levels; pre-, mid- and post-exercise/rest) and treatment (2 levels; exercise and rest) on HR, $F(1.64, 123.12) = 132.83, p < 0.001$ (See Figure 3.2).

![Figure 3.2. Mean (SEM) heart rate before, during, and after treatment in the exercise and rest conditions](image)

**Task effects**

There was no significant interaction effect of stress condition by time (6 level; before and during the 1st Stroop task, before and during 2nd Stroop task, before and during 3rd Stroop task) on HR, $F(3.03, 212.12) = 0.26, p > 0.05$. Surprisingly, the average HR before the task [High stress = 80.79 (10.36) bpm, Low stress = 79.68 (11.32) bpm] and during the task [High stress = 78.76 (10.07) bpm, Low stress = 78.00 (10.11) bpm] under the two stress conditions were not significantly different.

Mixed measures ANOVAs revealed that there was a significant interactive effect of stress condition (high and low) by time (4 level; before the stroop task, after 1st Stroop task, 2nd Stroop task, and 3rd Stroop task) for FS, $F(3, 228) = 8.05, p < 0.001$, but not for FAS, $F(1.89, 143.94) = 2.64, p = 0.08$. A FS and FAS score for the three tasks as a whole was calculated to be used in
a two way ANOVA (condition × task) (See Figure 3.3 & 3.4). The results showed no significant interaction effects for FS and FAS, but there was a main effect of task on FS ($F(1, 74) = 11.31, p = 0.001$), and a main effect of exercise on FAS ($F(1, 74) = 4.37, p < 0.05$). Figure 3.3 shows that FS was significantly lower in the high stress conditions [M (SEM) = 1.75 (0.26), compared with in the low stress conditions (M (SEM) = 3.01 (0.27)].

**Figure 3.3.** Mean (SEM) FS scores after cognitive challenge task by condition and task demand

Figure 3.4 shows that FAS was significantly higher in exercise condition [M (SEM) = 4.04 (0.19)], compared with in rest condition [M (SEM) = 3.50 (0.19)]. Thus, as a manipulation check of task, exercise had effect on FAS, but not on FS, and the cognitive challenge task had an effect on FS, but not FAS, during the task.

**Figure 3.4.** Mean (SEM) FAS scores after cognitive challenge task by condition and task demand

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Furthermore, there was no interaction effect of condition × task on perceived task demands and the number of mistakes, but there was a main effect of task. The high stress condition showed a higher perceived task demands \([M (SD) = 4.10 (1.26)]\) than in the low stress condition \([M (SD) = 1.26 (1.11)], F(1, 76) = 110.23, p < 0.001.\) The conditions induced a total number of mistakes of 55\% and 7\% of trials across the three blocks for the high and low demanding task, respectively. The perceived task demands was correlated with the total number of mistakes during the task \((r = 0.70, p < 0.001).\) The greater the perceived difficulty to do the task, the more mistakes were made.

### 3.3.3. Effects of condition and task on chocolate consumption

A two-way ANOVA revealed that there was no interaction effect of condition and task on total chocolate consumption, \(F(1, 74) = 0.20, p > 0.05,\) or main effect of stress, \(F(1, 74) = 0.07, p > 0.05.\) However, there was a significant main effect of exercise on total chocolate consumption, \(F(1, 74) = 7.12, p < 0.01.\) The mean (SEM) chocolate consumption for the exercise and control groups was 15.60 (3.51) grms and 28.84 (3.51) grms, respectively (see Figure 3.5).

![Figure 3.5](image-url)  
**Figure 3.5.** Interaction effects of stress and treatment condition in total chocolate consumption

A t-test revealed a significant difference between the groups \((t(73.53) = -2.69, p = 0.009, 95\% \text{ confidence interval (CI) for difference } -22.95 \text{ to } -3.41, \text{ effect size (ES) 0.61}).\) The pattern of results show that only during low stress task, exercisers consume less chocolate \([M (SEM) = 15.16 (5.02) \text{ grms}]\) than those in the rest group \([M (SEM) = 30.60 (5.02) \text{ grms}], t(36) = -2.06, p = 0.047.\) There were no significant differences in consumption between exercise and rest group during the high stress task, \(t(38 ) = -1.69, p > 0.05,\) although there was clearly a trend towards greater consumption in the rest condition. Given that 14 participants chose not to eat any chocolate it was considered whether to include them in the analysis, to compare with previously
conducted studies in which participants were told to eat chocolate. In an exploratory analysis, without these 14 participants, the results were similar to earlier analysis (i.e., no interaction effect of condition × time, no main effect of stress) and the effect size for the difference between exercise and rest group was even larger ($t(62) = -3.11$, $p = 0.003$, 95% CI for difference -26.39 to -5.74, ES 0.78). The measures of general characteristics (i.e., FCQ-T & DEBQ scales) were added as covariates to all the above model, but there was no effect on the results.

### 3.3.4. Effects of visual stimuli on chocolate craving

There were no significant interactive effects of condition by stress and time (2 levels; before and after opening the chocolate bar) on chocolate craving, $F(1, 74) = 0.22$, $p > 0.05$, as shown in Figure 3.6. However, there was a significant main effect of time on chocolate craving, $F(1, 74) = 21.94$, $p < 0.001$, with increases in cravings for all groups after opening a chocolate bar, irrespective of condition and stress level ($p > 0.05$).

![Figure 3.6](image.png)

Notes: Time 1 = before chocolate cue; 2 = after opening chocolate bar

**Figure 3.6.** The mean (SEM) desire scores of FCQ-S by time (pre and post chocolate cue)

### 3.3.5. Mechanisms

**Effect of exercise on FS and FAS**

Mixed measures ANOVA revealed that there was a significant condition (2 levels; exercise and control) by time (3 levels; before-, during- and after treatment) interaction effect for scores measured by the Feeling Scale, $F(1.59, 120.49) = 4.71$, $p = 0.017$. Post-hoc t-tests revealed that
FS scores were significantly greater after the exercise condition, compared to the rest condition, $t(76) = 2.94, p < 0.01$ (95% CI 0.33 to 1.72, ES $d = 0.67$), but not during treatment, $t(76) = 0.06, p > 0.05$. Figure 3.7 shows the mean FS scores at each assessment in the exercise and rest condition.

Figure 3.7. Mean (SEM) FS scores before, during, and after treatment in the exercise and rest conditions

Mixed ANOVA indicated that there was a significant condition by time interaction effect for the Felt Arousal Scale, $F(1.64, 124.59) = 11.00, p < 0.001$. Figure 3.8 shows the mean FAS scores in the exercise and rest conditions, across time. FAS scores of the exercise group were significantly greater during ($t(67.43) = 6.31, p < 0.001; 95\%$ CI 1.09 to 2.09, ES $d = 1.42$) and after treatment ($t(67.66) = 6.46, p < 0.001; 95\%$ CI 1.28 to 2.42, ES $d = 1.45$) compared to the rest group.

Figure 3.8. Mean (SEM) FAS scores before, during and after treatment in the exercise and rest conditions
Affective mediators of the effects of exercise on chocolate consumption

Regression analysis was carried out as recommended by Cerin (2010) and Baron and Kenny (1986) to examine the mediating effect of FAS in the relationship between exercise and chocolate consumption (see Figure 3.9). FS was not correlated with condition (X) and chocolate consumption (Y), so was not considered in a mediation analysis. FAS, at time point 4 (after first dot probe task, which is the same time point as initial chocolate consumption), was used as a mediator. The analysis was carried out by involving data from both stress conditions first and then for each stress condition separately as shown in Figure 3.9.

Note. \( b \) – Beta value as a sole predictor; \( b_1 \) – Beta value after adding mediator

**Figure 3.9.** Diagram of the mediating effects of FAS on the relationship between condition and chocolate consumption
The results show that there was no mediating effect of FAS in the relationship between exercise and chocolate consumption with all participants included in the analysis and with only those in the low stress condition. There was a slight trend towards a mediating effect of FAS in high stress condition (see (2) in Figure 3.9). In other words, all bi-variate correlations were significant and when adding FAS to the model with condition as a predictor of chocolate consumption the direct effect of condition disappeared. Interpretation was difficult though as the effect of FAS on consumption was also no longer significant ($p = 0.069$).

3.5. Discussion

This is the first study to explicitly recruit regular chocolate eaters to examine the effects of moderate intensity exercise, compared with rest, on ad libitum chocolate consumption. The main aim of this study was to examine whether a 15 minute bout of brisk walk could moderate the effects of stress on chocolate consumption, attenuate chocolate cravings induced by visual stimuli. The experimental situation led to a wide variation in ad libitum chocolate consumption and changes in chocolate cravings, but this variability was largely not explained by stress manipulations in the study. Exercise reduced chocolate consumption and the effect seemed to be influenced by affect. However, exercise did not attenuate increases in cue-elicited cravings after the task. These findings will be discussed with reference to (1) responses to stress; (2) exercise dose; (3) opening a chocolate bar to elicit cravings; (4) sample characteristics; (5) factors that may have influence chocolate consumption and related measures.

3.5.1. Responses to stress

The aim was to increase stress with an expectation that under high stress more chocolate would be eaten than under a low stress condition. The high stress group reported that the task was more demanding than did the low stress group, and the high stress group made more mistakes during the task than the low stress group. Although FS was significantly lower during the high demanding task (compared to low demanding task), in general, measures of FS and FAS were fairly consistent from before to after three blocks of the task, in both conditions, with one exception. Scores on the FS were lower after the 1st high stress task, but not after task 2 and 3.

HR did not increase while performing either the high or low stress tasks. Based on the previous research (Jouven, Schwartz, Escolano, Straczel, Tafflet, & Desnos et al., 2009), tasks under high stress are expected to increase HR. However, there was no difference between high and
low stress, in response to the two tasks in the present study. Stress has successfully been manipulated to increase chocolate eating (Zellner et al., 2006), but the present study may not have involved a demanding enough challenged in the high stress condition.

Cognitive demand might be a confounding factor in some of the tasks used to induce stress in the laboratory (Ward & Mann, 2000). Some studies have successfully used the Stroop task as a method for inducing stress (Taylor & Katomeri, 2007; Taylor & Oliver, 2009; Wallis & Hetherington, 2004; Cattanach, Malley, & Rodin, 1988). Taylor and Oliver (2009) reported that the Stroop Colour-Word Interference Task also increased chocolate craving. They used 4 colour-words or 8 colour-words in the incongruent condition, and four response keys, and 3 min tasks repeated two times (Taylor & Oliver, 2009). However, in the present study, there were differences in the repeated time, numbers of colour presented, and numbers of response key. Three 3 min tasks, three colour-words (red, blue, and green) and three keys for response may have been less challenged. Previous studies to investigate the effect of stress on food intake have used a speech task (Goldfield et al., 2008; Oliver et al., 2000), ego-threatening stress (Schotte, Cools, & McNally, 1990) and electrical shock (Heatherton et al, 1991a) as a stressor. This may imply that a greater challenge or the other mood inducing tasks (ego-threatening) could have led to greater increases in craving for a sugar snacking. Simulating real life stressors is notoriously challenging. The precise nature of stress that leads to greater sugar snacking is not clear, but the present study suggests that simply completing even a challenging form of the Stroop task may have been insufficient to manipulate stress.

If anything, the low stress group ate more chocolate but only after the passive condition. One possible reason why low stress induces greater chocolate consumption is boredom. Thayer (2001) states that boredom, which is a condition of tense tiredness and underlying negative mood, is a stimulus to eating. He explained that food is the immediate cure for boredom and raises energy with a corresponding reduction of tension. Hill (2007) also noted that craving for sweets was closely associated with snacking and boredom. Kerr (2005) suggested that low levels of felt arousal are experienced as unpleasant anxiety and boredom. In the present study, FAS showed small but non-significant reductions across each subsequent task and this may have been symptomatic of increased boredom, causing some participants to eat more chocolate.

3.5.2. Exercise dose

The hypothesis was that exercise may moderate the stress response and hence reduce stress-induced chocolate intake. Other studies have shown that moderate intensity exercise reduces anxiety and arousal from pre-exercise (Taylor, 2000), and stress reactivity after exercise (Hamer
et al., 2006; Taylor & Katomeri, 2007). In the present study the exercise group reached 28.75% of HRR, had a mean HR of 116.35 bpm and had an RPE between 11-13 (i.e., low-moderate intensity exercise) conditions (ACSM, 2006). One weakness of the study is that an initial VO$_2$ max test was not conducted to more precisely determine individual heart rate at a moderate intensity. However, the use of RPE and self-regulation of intensity has been shown to accurately involve people at a moderate intensity. It therefore seems unlikely that the dose of exercise was insufficient to attenuate responses to stress in the present study. It is more likely that the stressor was insufficient to observe any effect of exercise.

It is unclear what duration and intensity of exercise is most effective to reduce appetite and craving for certain types of food. In the Thompson et al (1998)’s study, hunger was suppressed in the high-intensity exercise condition (68% VO$_2$ max) compared to low-intensity exercise (35% VO$_2$ max). Bozinovski and colleagues (2009) stated that short-duration exercise was an effective strategy for decreasing average appetite, desire to eat, and hunger. The current study focused on the effects of an easily attainable short walk which could be easily achieved for everyone, compared with higher intensity or longer duration exercise. Findings in the present study are in line with Bozinovski and colleagues’ study (2009) and support two previous studies showing that a brisk walk reduces chocolate craving among abstinent regular chocolate eaters (Taylor & Oliver, 2009), and that a 5 min brisk walk reduces urges to snack (Thayer et al., 1993). The findings also support previous evidence that exercise suppresses appetite (Blundell & King, 2000; Maraki et al., 2005; King et al., 1994). The mediation analysis in this study provided limited support that the effect of exercise on ad libitum chocolate consumption may be mediated via changes in affective activation (FAS), but only in the high stress condition ($p = 0.069$). Further research is needed to explore the mediating role of affect on chocolate consumption with a larger sample size.

3.5.3. Opening a chocolate bar to elicit cravings

Conditioning processes cause physiological and subjective response like hunger and craving to conditioned cues (e.g., cues involving mood disturbances or exposure to inhibited cues) (Tuomisto et al., 1999; Wardle, 1990). We salivate when we hear, see or smell something associated with a reward and the presentation of likeable foods make us crave more and eat more because we think about them more (Wansink, 2006). Fedoroff and colleagues (2003, 1997) found that there was an increase in subjective desire to eat, liking, and craving for a particular food after exposure to the smell of target food among restrained eaters. As expected, in the present study after opening a chocolate bar and imaging its taste and smell, participant’s desire to eat a chocolate increased. Those in the high stress condition tended to increase their
craving more than those in the low stress. Taylor and Oliver (2009) suggested that a 15 min bout of brisk walk could reduce cue-elicited chocolate craving. However, the present study did not support such an effect after involvement in a cognitive challenge task following exercise. Compared to Taylor and Oliver’s study (2009), in the present study FCQ-S scores in the exercise condition were similar. However, those scores in the rest group appeared to be lower than those in the previous study (See Table 3.3). Regarding testing time, King and colleagues (1994) reported that appetite suppression following exercise was short-lived and recovery was rapid. Hunger tended to return to near control levels within 15 mins. In the present study it was 20 mins after the exercise before the participants opened the chocolate, by which time there may no longer have been an effect from such a low dose of exercise.

**Table 3.3.** The Scores on FCQ-S compared with other sample (Taylor & Oliver, 2009)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Current study</th>
<th>Taylor &amp; Oliver, 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exercise</td>
<td>Rest</td>
</tr>
<tr>
<td>Pre opening</td>
<td>9.4 (2.9)</td>
<td>9.3 (2.8)</td>
</tr>
<tr>
<td>Post opening</td>
<td>10.7 (2.9)</td>
<td>10.2 (2.9)</td>
</tr>
<tr>
<td>Dimension 2 (post)</td>
<td>10.5 (2.9)</td>
<td>9.9 (3.0)</td>
</tr>
<tr>
<td>Dimension 3(post)</td>
<td>9.2 (3.3)</td>
<td>9.3 (2.5)</td>
</tr>
<tr>
<td>Dimension 4(post)</td>
<td>9.2 (3.2)</td>
<td>8.5 (2.8)</td>
</tr>
<tr>
<td>Dimension 5(post)</td>
<td>9.2 (2.6)</td>
<td>8.6 (2.8)</td>
</tr>
</tbody>
</table>

Note: Dimension 1: an intense desire to eat; Dimension 2: anticipation of positive reinforcement that may result from eating; Dimension 3: anticipation of relief from negative states and feelings as a result of eating; Dimension 4: obsessive preoccupation with food or lack of control over eating; Dimension 5: craving as a physical state

3.5.4. Sample characteristics

In the previous studies related to stress and eating behaviour, university students have been commonly used as participants (Zellner et al., 2006; Shapiro & Anderson, 2005; Macht, Haupt, & Ellgring, 2005), which may have limited generalisability to the general population. In the present study, participants were recruited through public messages, not just in the University, as reflected in the wide age range of the sample.

It is expected that chocolate consumption may have been greater among those with higher trait scores as indicated from the DEBQ and FCQ-T. Regarding FCQ-T, the mean items scores were fairly similar across three studies (see Table 3.4).
Table 3.4. The scores on FCQ-T compared with other samples (Taylor & Oliver, 2009; Rodriguez, 2005)

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD) / items</td>
<td>3.6 (1.3)</td>
<td>3.6 (0.8)</td>
<td>3.9 (1.8)</td>
</tr>
</tbody>
</table>

According to previous findings (Oliver et al., 2000; Tanofsku-Kraff et al., 2000; Rutledge & Linden, 1998; Greeno & Wing, 1994), restraint, emotional eating, and stress manipulations were found to interact such that restrained eaters and emotional eaters increased their eating during or following a stressful event, relative to unrestrained and unemotional eaters. Ward and Mann (2000) also suggested that cognitive demand disinhibits eating in restrained eaters. In the present study, counter to prediction, the restrained and unrestrained, emotional and unemotional participants did not differ in the amount of chocolate eaten between the exercise and rest group, or between the high and low stress group.

It may not be surprising that the effects of condition × time on chocolate consumption were not changed by adding trait variables as covariates. The items in these scales focus on emotions and affect in terms of positive and negative affect, rather than a tendency to eat high energy foods when in a deactivated state. However, further research with larger samples is needed to test the three way interaction between participant characteristics, exercise and stress on eating.

Other participant characteristics may also have influenced the results. Previous research (Long, Hart, & Morgan, 2002; Ruderman & Christensen, 1983; Herman & Mack, 1975) showed that the effects of preload on food intake can influence subsequent eating. Ruderman and Christensen (1983) found that overweight individuals ate less after the preload, and normal weight people ate slightly more. In the present study, those who did not eat any chocolate during the tasks, reported that they could not eat any chocolate because they had not yet eaten breakfast and they did not want to eat any chocolate before planned eating after the session (due to the timing of the sessions). Further research could standardise preload to control for variability in desire for chocolate at baseline although there is no reason to believe that the groups in the present study were different. Also, participants should be asked about their dieting (dieter or non-dieter) and exercise history (regular exerciser or non-regular exerciser). Although the present study was not large enough to conduct further analyses by sub-groups such information may have qualitatively helped to understand variability in eating response to exercise. For example, the perceived intensity of exercise could be different depend on the
exercise history; sedentary people could rate the same exercise to be more intense than regular exercisers.

3.5.5. Other factors that may have influence chocolate consumption and related measures

No previous study has examined the complex interaction effects of exercise and stress on eating behaviour. In this study, aspects of the methodology were based on previous studies concerned with stress and eating, with some differences. One difference between the present study and previous studies involving measurement of ad libitum eating was the placing of a bowl of chocolate and the existence of an observer. In this study, the chocolate bowl was on the desk beside the computer during the Stroop task. Participants were informed that the chocolate had been left from a previous seminar and they were invited to help themselves. They were not left alone during the Stroop task because the existence of an observer could increase their stress response during the task.

It was not anticipated that participants would eat chocolate while performing the tasks, only between or after the final task. Nevertheless some participants managed to eat during the low stress task. This potentially contributed to greater consumption in the low stress condition due to more time to eat. In contrast, in another study concerned with chocolate consumption after completing the Stroop task, a bowl of chocolate was presented and participants were instructed that they could eat as much as they wished and were left alone to eat over a period of 10-15 mins (Macht and Mueller, 2007; Wallis & Hetherington, 2004). Also, Ward and Mann (2000) asked participants to consume food as a means of manipulating mood while performing the tasks. In the present study the focus was on ad libitum eating with a deliberate attempt to minimise a focus on this being a main part of the study. The current study did not ask participants to eat chocolate while performing but they were told to help themselves. This may be an important aspect to consider in future studies. Exploratory analysis of data in the present study revealed that when those who ate no chocolate at all were removed the difference between exercise and rest condition was greater especially in the low stress condition.

The type of chocolate also could be a limitation of this study. The types of chocolate available in this study may not have been appealing. Macht and Mueller (2007) stated that eating palatable chocolate improves negative mood, and increases joy, but mood state after eating unpalatable chocolate did not have any effect on mood state. In this study, I tried to give more choice (e.g. ‘buttons’ and back and white ‘maltese’), but it may not have been enough to be a palatable chocolate for all participants.
Lastly, gender difference also could be considered. In previous research, Grunberg and Straub (1992) found that men in the stressed group ate less than men in the control group. However, in women there were no significant differences, although stressed women did show a trend toward a modest increase in consumption of sweet and bland foods with no change in intake of salty foods. Zellner, Saito, and Gonzalez (2007) reported that there were differences in food selection when under stress between men and women. The present study involved a mix of males and females. Although gender did not appear to moderate any effects of exercise there may have been insufficient numbers of each to show sub-group effects.

**Practical implications**

A 15-min brisk self-paced brisk walk is a small dose of physical activity that can be easily achieved. Previous research had focused on how different (high) doses of exercise impact on appetite and hunger, and chocolate cravings, but evidence that short bouts can have effects on stress-related eating could have important practical implications. However, the present study does not provide clear support to suggest that a 15 min brisk walk has any practical utility for suppressing stress induced consumption of chocolate. Other studies have shown that stress does induce greater consumption. Williams’s study (2008), based on Hedonic Theory (Bentham, 2007) and Expectancy Theory (Kirsch, 1990) explained that the perceived positive affective response and experience will determine subsequent repeated events. In relation to the current study, the positive experience from eating chocolate (or other food) under stress or with increased craving will be memorised as a positively affective response to the behaviour, and the behaviour will be repeated. However, if hedonic eating is replaced by exercise before situations when cravings are likely to increase then physical activity may be a behavioural treatment for contributing to overeating and obesity.

The findings in this study add some support to previous studies that have shown an effect of exercise on self-regulation and inhibition across a number of health behaviours. Other addiction research has found that a single session of exercise reduced self-reported urges to smoke, *ad libitum* smoking (Taylor & Katomeri, 2007; Ussher et al., 2008), attentional bias to smoking cues (Janse Van Rensburg et al., 2009a) and alcohol urges (Ussher et al., 2004). Repeated bouts of short moderate intensity physical activity (e.g., brisk walking) may lead to enhanced chronic self-regulation of eating. Conversely, sedentary behaviour may lead to poor self-regulation of emotional eating. Pomerleau and colleagues (2004) also reported that an acute bout of low-moderate intensity exercise had more favourable effects on energy intake than rest or vigorous exercise.
Research implications

Further research, with a larger sample size, is needed to further examine the mediating effects of exercise on mood inducting tasks (e.g., mentally challenging, ego threatening, or deactivating-boring) and chocolate consumption and related thoughts. There have been some studies involving eating and mood induction; anger, fear, sadness, joy, tension, relaxation (Macht & Simons, 2000; Macht, 1999), anxiety (Goldfield & Legg, 2006; Steer & Cooper, 1993), but not for boredom. Lastly, the present study attempted to simulate a workplace where snacking takes place but there is scope to examine the effects of exercise on eating in other natural environments.

Conclusion

In conclusion, physical activity plays an important role in energy balance and general appetite suppression. The present study suggests that a brief bout of physical activity may reduce ad libitum eating of chocolate irrespective of level of stress from a mental challenge in a simulated work place. Chocolate visual stimuli increased the desire to eat the chocolate, especially under high stress, but exercise did not attenuate these increases. Further research is needed to explore how exercise impacts on mood-induced eating behaviour, particularly high energy snacking. Also, overweight and obese individuals should be involved and the effects of brief bouts of low-moderate intensity physical activity should be explored as part of a weight management programme.
Chapter 4. Study 2

The acute effects of moderate intensity exercise on hedonic food cravings and attentional bias (the visual dot probe task) among normal weight and overweight females during temporary and naturalistic (during Lent) abstinence.

4.1. Introduction

The previous study (Study 1) looked at the acute effects of exercise on self-reported craving and *ad libitum* chocolate consumption and found that participants who took a 15min-brisk walk ate less chocolate compared with those in the passive condition. It is unclear why this happened and one explanation may be that the chocolate grabbed the attention of the regular chocolate eaters which led to an elevated craving to eat and then failure to inhibit a behaviour. There is therefore a need to consider if exercise affects attentional bias to snacking cues/images.

Studies investigating cravings to certain types of food or substances have been extending their interest from simple self-reported measures of craving to cognitive mechanisms (e.g., attentional bias, Miller & Fillmore, 2011; Tapper, Pothos, & Lawrence, 2010). The Incentive-Sensitization Theory (Robinson & Berridge, 1993) and Elaborated Intrusion (EI) Theory (Kavanagh, Andrade, & May, 2005) give theoretical support for cue-elicited cravings (imagery-based cognitive elaboration) and focused attention on the cues. EI theory especially emphasises the importance of intrusive thoughts and vivid sensory images (May, Andrade, Batey, Berry, & Kavanagh, 2010). Field and Cox (2008) reviewed the evidence of attentional bias to addictive behaviour and they stated that substance use is described by biases in the attentional processing of substance-related stimuli which acquire the ability to grab the subject’s attention. In addiction research, attentional bias is regarded as an important factor to predict substance-seeking behaviour (Field, Munafo, & Franken, 2009). For instance, attentional bias has been associated with self-reported craving (Mogg, Bradley, Field, & De Houwer, 2003; Field et al., 2009), the level of dependence on a substance (Mogg et al., 2005), and repeated unsuccessful quit attempts (Bradley, Mogg, Wright, & Field, 2003).

There are several ways to measure attentional bias such as the Stroop task (Johansson et al., 2004), the dot probe task (Ahern et al., 2010), and use of an eye-tracking system (Nijs et al., 2010). Among indirect measures of attentional bias (e.g., stroop task, dot probe task), the visual dot probe task measures how subject’s attention is allocated to cues (Field & Cox, 2008). Kemps and Tiggemann (2009) found attentional bias for chocolate related cues by using a dot
probe task with pairs of chocolate/food and food/food (control) pictures presented for 500ms among chocolate cravers compared with non-cravers.

Some studies have tried to measure initial attentional bias and maintained attentional bias by presenting stimuli for different durations (e.g., 500ms and 1000ms, Brignell et al., 2009; or 100ms and 500ms, Nijs et al., 2010). Attentional system is not unitary and it may operate in two different attentional processes such as automatic capture and maintained attentional bias (Field & Cox, 2008). Initial attentional bias indicates a fast and automatic bias in the shifting of attention when stimuli are presented in short exposure duration and maintained attentional bias is the subsequent maintenance of attention when longer exposure duration was used (Field & Cox, 2008).

Several factors may influence craving and attentional bias to food cues, such as individual differences and duration of deprivation from the specific food. Different responses between low and high BMI groups on food cues have been reported in the literature (Nijs, Muris, Euser, & Franken, 2010). In a review paper, Volkow and colleagues (2011) reported that obese subjects showed increased activation of reward-related brain regions (e.g, NAc, ACC, amygdale, hippocampus) when they were exposure to high-calorie foods compared with normal weight people. Ferriday and Brunstrom (2010) found that after cue exposure an overweight group showed greater response and greater motivation to consume food than a normal weight group. In an attentional bias study, overweight females tended to have greater initial attentional bias to food in the hunger condition (Nijs et al., 2010) and gazed longer at food in the fed condition compared with normal weight females (Castellanos et al., 2009). However, these studies were about general food cravings and no study has examined attentional bias to chocolate with elevated hedonic hunger rather than homeostatic hunger specifically among high chocolate cravers.

Impulsivity as a personality trait (i.e., a tendency to act without thought) is highly correlated with health-related problems and the failure to self-regulate (Hofmann, Friese, & Wiers, 2008). Few studies of addiction and binge eating have examined the relationship between impulsivity and cue reactivity (Papachristou, Nederkoorn, Haermans, van der Horst, & Jansen, 2011; Guerrieri et al., 2007). Nasser and colleagues (2004) found that binge eating disorder positively correlation with impulsivity among obese women. Also, Guerrieri et al. (2007) reported that state/trait impulsivity predicted food intake among normal weight women. It would therefore seem important to consider if personality traits such as impulsivity moderate cue-elicited cravings and related constructs such as attentional bias.
In terms of duration of deprivation, regional brain activation appears to differ between a fasted (overnight fasting and skipping breakfast) and fed condition (overnight fasting and eating breakfast) (Goldstone et al., 2009). After a fasting condition there was increased brain activation (e.g., amygdala, anterior insula, OFC) when exposing high-calorie food pictures compared with low-calorie foods. The study focused on comparing different nutritional state, rather than different levels of hedonic hunger. In chocolate craving studies, to elicit craving, participants were asked to abstained from eating chocolate for between 24 hours (Tiggemann, Kemps, & Parnell, 2010; Van Gucht, Vansteenwegen, Beckers, Herman, Baeyens, & Van den Bergh, 2008) and 3 days (Taylor & Oliver, 2009), and it may be that an even longer-term abstinence (e.g., over 1 week) elicits greater cravings. Given that Lent is a period during which people naturally abstain from eating chocolate, it may be expected that images of chocolate may elicit greater cravings and attentional bias during deprivation.

Using eye tracking technology, moderate intensity exercise can reduce attentional bias toward smoking-related stimuli (Janse Van Rensburg, Taylor, & Hodgson, 2009a) and chocolate-related stimuli (Taylor et al., 2009). However, no study has measured the effect of exercise on attentional bias to food cues using an indirect measure of attentional bias (visual dot probe task). There is a need to examine if the different measure of attentional bias shows the same effect as the direct measure of attentional bias.

In this study, it is hypothesised that brisk walking will cause a decrease in attentional bias and subjective cravings, compared with a passive control condition among regular chocolate eaters. This would be reflected in slower reaction time after exercise in trials where a dot probe appears after the salient (chocolate) image compared with a neutral image when pairs of images are presented together. There may be differences in these effects for measures of initial and maintained attentional bias. Also, the effects may be more evident among those who are overweight, more impulsive, have a greater tendency to be an emotional eater, and have stronger trait chocolate cravings. If there are any effects of exercise on attentional bias there is a need to understand why these effects occur. One idea is that exercise enhances affect which in turn reduces an interest and need to engage in hedonic eating. Reductions in attentional bias and subjective cravings may be associated with (or mediated by) changes in affect (FS and FAS) in response to exercise.

Thus, this study had one main aim and several secondary aims. The main aim was to assess whether a 15-minute brisk walk, compared with a passive rest condition, decreased both initial and maintained attentional bias to chocolate images, using the dot probe task and self-reported craving for chocolate. Secondary aims were to examine if any effects of exercise were moderated by BMI and other trait measures (e.g., impulsivity, TFEQ-R18, FCCQ-T, trait hedonic
hunger) and duration of deprivation from chocolate; to examine whether changes in affect (FS & FAS) mediated any effects of exercise on attentional bias and self-reported craving for chocolate.

4.2. Methodology

4.2.1. Participants

One hundred and ten people responded to public poster advertisements and e-mails sent through University networks. Examples of the adverts are shown in Appendix 4. To minimise priming of participants about the exact nature of the study, the study was described as concerned with exercise and cognitive function. Responders were requested to confirm that they met the inclusion criteria of being a regular chocolate eater (i.e., regular chocolate eaters; at least 100g of chocolate or 2 chocolate bars per day) and females only. They were also asked three questions: 1) “how would you describe the experience of eating chocolate?”; 2) “How often do you have cravings for sweets”; 3) “How often do you have cravings for chocolate”, using a 6-point scale (1 = very unpleasant/strongly disagree, 6 = very pleasant/strongly agree). The individual scores of these three questions were added up to provide a total score. Those scoring 12 or above were eligible to enter the study. Participants also had to be able to safely do at least 15 mins of moderate intensity exercise. As shown in Figure 4.1 at the initial screening, of 25 normal weight volunteers 5 people were excluded, and of 49 overweight volunteers 19 people were excluded as they were not regular chocolate eaters (at least 100g of chocolate per day).

Figure 4.1. Study overview
Thirty six people who reported to have given up eating chocolate for Lent responded to adverts. Among them, 6 people who were not regular chocolate eaters prior to Lent were excluded. However, 9 overweight and 8 Lent group participants did not turn up for the 1st assessment and a further 5 people in the Lent group ate chocolate before the testing day and were therefore not randomised. Thus, in total the sample included 20 normal weight (BMI < 25), 21 overweight females (BMI > 25) undergoing temporary chocolate abstinence, and 17 females (12 normal weight and 5 overweight) who were abstinent from chocolate during Lent.

The mean (SD) score for the 3 initial criteria questions of participants was 15.38 (2.03) on a scale from 3-18. There is no absolute clinically meaningful change in attentional bias that is worth powering a study on, and no studies have previously investigated the effects of exercise on attentional bias using the proposed measure. However, G*Power3 statistical power analysis program was used to calculate the minimum sample size. As a best estimate it was examined the differences in attentional bias post treatment (i.e., after exercise and rest), using dwell time (a visual attentional bias measure using eye tracker technology) determined in a previous study (Taylor, Oliver & Janse Van Rensburg, 2009). With an alpha level of 0.05 and power (1 - β) of 0.95 we estimated that 19 participants are needed to identify a statistically significant difference, for a within subject comparison (post exercise v rest). In addition, the differences in subjective craving between exercise and rest were used from Taylor and Oliver (2009). With an alpha level of 0.25 and power (1 - β) of 0.80 (effect size 0.53), we estimated that 15 participants are needed to determine a significant difference. It is not clear what differences in the effects of exercise will exist between normal and overweight participants, or between temporarily abstinent and longer-term abstinent (during Lent) so we aimed to recruit 20 participants in each group.

4.2.2. Procedure

All procedures were approved by the University of Exeter Research Ethics Committee and subjects received information sheet (see Appendix 1). Prior to arrival, normal weight and overweight participants (non-Lenters) were asked to record a 4-day chocolate diary (see Appendix 5), with a request to abstain from snacking for the 4th day (24 hours abstinence) guided by previous research (Tiggemann et al, 2010). Participants who took part in Lent were asked to abstain from chocolate for at least 1 week. After eating a normal meal (breakfast or lunch), they were asked not to eat, drink (except water) or exercise for 2 hours prior to coming to the lab for each session. The overall procedure is shown in Figure 4.2.

Upon arrival on Day 1, participants provided written informed consent, and were screened using the SSHS Physical Activity Readiness Questionnaire. Physical activity was measured using the
7-day recall of Physical Activity questionnaire (Blair et al., 1985). They were asked to submit the chocolate diary at the same time to check how many hours it had been since their last meal and consumption of chocolate and a structured interview was recorded by voice recorder to check their motivation and attributions for eating chocolate. Then each group (normal, overweight, and Lenters) were randomly assigned, in a counterbalanced design, to engage in two conditions: being passive for 15 mins and doing a 15 min brisk walking on different days.

<table>
<thead>
<tr>
<th>Time Line</th>
</tr>
</thead>
</table>
| Food diary, interview | T1: Craving, hunger, FS, FAS  
| Baseline measures |  
| 5 min | Go/No-go task  
| 10 min | The Visual Probe Task1  
| 15 min | Exercise/Rest  
| 30 min | The Visual Probe Task2  
| 35 min | 5 mins after the task  
| | T2: Craving, hunger, FS, FAS  
| | T3: Craving, hunger, FS, FAS  
| | T4: Craving, hunger, FS, FAS  
| | T5: Craving, hunger, FS, FAS  
| | T6: Craving, hunger, FS, FAS  
| | Time next chocolate eaten (from text message)  

**Figure 4.2.** The time frame for measures

On the first day, screening and baseline assessments were conducted before randomisation, and involvement in the first treatment. The participants were initially fitted with a heart rate monitor to be worn throughout the session to measure exercise intensity. At baseline, participants were asked to answer several trait-like questionnaires to determine eating behaviour and impulsivity. After the baseline screening and measurements, participants were asked to choose their favourite chocolate bar from a basket of fun-size wrapped chocolate bars and to write down the name of the chocolate bar. Participants rated their level of chocolate cravings and affect during the testing session at the following times: 1) on arrival at the laboratory (after picking their favourite chocolate); 2) after 1st visual dot probe task; 3) mid-treatment (exercise or passive condition); 4) post-treatment; 5) after 2nd visual dot probe task; 6) at 5 minutes after the task.

**Exercise treatment:** The exercise session consisted of a 2 minute warm-up, followed by a 15 minute semi self-paced brisk walk on a treadmill. To monitor the participants’ exercise intensity,
heart rate and Rating of Perceived Exertion (RPE, Borg, 1998) using a scale ranging from 6 (very, very light) to 19 (very, very hard) were used. Participants were instructed to work at a level between 11 (fairly light) and 13 (somewhat hard) ‘as if late for a bus or appointment, but not to the point of breathlessness.’ The participants were told, “I would like you to keep the same level of RPE while exercising”, that is between 11-13 on the RPE scale.

**Passive treatment:** Participants were required to sit passively and quietly at a desk for 15 minutes with no reading materials.

Attentional bias was measured by the visual dot probe task. The participants were seated at a desk in front of a computer and asked to do experimental task before and after treatment. After the 2nd visual dot probe task, participants were seated for 5 minutes in a quiet room. After that, the level of subjective hunger, chocolate craving and affect were recorded. Participants were asked to take the chocolate which they had chosen at the beginning of the session, when they left the laboratory. The time from leaving to eating the next chocolate was calculated from the time of a text message sent from the participant’s mobile phone. The Lent group was excluded from this task as they were not planning to eat any chocolate until the end of Lent. At the end of the 2nd laboratory session, participants received a payment of £15 for their participation in the study.

4.2.3. Measures

4.2.3.1. Background measures.

**Trait measures.** The questionnaires are shown in Appendix 6. Eating behaviours were measure by the Three-Factor Eating Questionnaire-R18 (TFEQ-R18; de Lauzon, Romon, Deschamps, Lafay, Borys, & Karlsson et al., 2004) on a 4-point response scale (definitely true/ mostly true/ mostly false/ definitely false). The item scores (1- 4) were summated for restrained eating (6 items), uncontrolled eating (9 items), and emotional eating (3 items). Trait chocolate craving was measured by the Food Chocolate-Craving Questionnaire-Trait (FCCQ-T; Cepeda-Benito, Gleaves, Fernandez et al., 2000b), which consists of 39 items on a 6-point scale from 1 (never or not applicable) to 6 (always). Power of Food Scale (Lowe, Butryn, Didie, Annunziato, Thomas, & Crerand et al., 2009) was used to measure trait hedonic hunger. This scale is an 15-item scale and consists of 3 subscales on a 5-point scale from 1 (I don’t agree at all) to 5 (I strongly agree): food available (e.g., “It seems like I have food on my mind a lot”), food present (e.g., “If I see or smell a food I like, I get a powerful urge to have some”), and food tasted (e.g., “Just before I taste a favourite food, I feel intense anticipation”). Impulsivity was measured by
two different measurements: self-report questionnaire (the Barratt Impulsiveness Scale, BIS-11; Patton et al, 1995) and laboratory measures (The Go/No-go task; Logna, Schachar, & Tannockm 1997). BIS-11 has 30 items and consists of 3 subscales: motor impulsivity (e.g., “I do things without thinking”), nonplanning impulsivity (e.g., “I plan tasks carefully”), and attentional impulsivity (e.g., “I don’t pay attention”). The 7-day recall of Physical Activity questionnaire was used to calculate energy expenditure (i.e., Daily energy expenditure: moderate exercise = 4METs, vigorous exercise = 8METs, sleeping = 1MET, light activity = 1.5 METs; total weekly energy expenditure (kcal/kg/wk) = (hrs of moderate exercise x 4Mets) + (hrs of vigorous exercise x 8Mets) + (hrs of light activity x 1.5Mets) + (Sleeping hrs x 1MET); Total daily energy expenditure (kcal/kg/wk/d) = (total weekly energy expenditure) / 7).

Go/No-go task. After answering trait-like questionnaires, a computerised Go/No-go task was used, modified from one used by Harrion, Coppola, and McKee (2009) and Fillmore, Ostling, Martin, and Kelly (2009). The Go/No-go task has been used to assess behavioural activation and inhibition in addiction research (Harrison et al., 2009; Fillmore et al., 2009; Dom, De Wilde, Hulstijn, van den Brink, & Sabbe, 2006) and was associated with self-report measures using the BIS-11 (Harrison et al., 2009); higher BIS-11 scores were related to lower inhibitory control on the Go/No-go task (Dom et al, 2006). The task was operated using E-Prime software to measure reaction time and errors performed. Participants completed a total of 110 trials, which took approximately 5 minutes. A trial involved the following sequence: a fixation (+) for 800ms; a blank, white screen for 500ms; a cue (a white rectangle) randomly displayed for one of five stimulus onset asynchronies (100, 200, 300, 400, and 500ms); a randomly displayed go or no-go target (green or blue rectangle) that lasted until the participant made a response or until 1000ms, whichever was the first; and an inter-trial interval of 700ms. Participants were instructed to press a key (0) only for green rectangles (i.e., go target) and to not respond for blue rectangles (i.e., no-go target). They were instructed to make fast responses but also to avoid mistakes. The cue (i.e., a rectangle) was presented either horizontally or vertically, with 55 trials of each. The total 110 trials presented the four possible cue-target combinations (horizontal cues with 80 % of go target and 20 % of no-go target, and vertical cues with 20 % of go target and 80 % of no-go target). Thus, an equal number of vertical (55) and horizontal (55) cues were presented before an equal number of go (55) and no-go (55) target stimuli. Outcome measures of interest were reaction time (RT) and inaccuracy errors in responding to go targets (response activation) and no-go target (failures of inhibition) after horizontal and vertical cues. A mean RT for each participant was calculated and individual RT that was less than 100ms or greater than 1000ms were excluded. Higher failure scores indicated poorer inhibitory control and longer mean reaction time showed slower response activation on a test.

A 4-day chocolate diary. In the diary, participants were asked to record when, where, and how many grams of chocolate they ate for 3 days (abstain from eating chocolate for the 4th day), with
feeling and felt arousal score at pre and post eating chocolate. From the diary, the general chocolate consumption for 3 days and the change scores of feeling and felt arousal were used to describe the participants’ characteristics.

Qualitative interviews. The motivation to eat chocolate was measured by a structured taped interview at the beginning of the baseline measurement to assess the links between some of the constructs assessed quantitatively and eating behaviour. The interview was conducted to confirm the triggers for eating chocolate and to highlight any apparent differences between the 3 groups (normal, overweight, and Lenters). The interview consists of 3 items (i.e., “where and when did you last eat chocolate?”, “I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing”, “Can you say why you wanted/needed chocolate at that particular moment”).

4.2.3.2. Main outcome measures

Attentional Bias. To assess attentional bias (i.e., initial and maintained attentional bias), a visual dot probe task, modified from Field, Mogg, & Bradley (2005), with chocolate-related pictures was used. Various image exposure duration has been used in previous research (e.g., 500, 1000, 2000ms). Bradley, Field, Mogg & De Houwer (2004) used 200 and 2000ms duration in a study on alcohol attentional bias with heavy and light social drinkers, and Tapper et al. (2010) used 3 different stimulus durations (100, 500, and 2000ms) to examine food-related attentional bias. Bradley, Garner, Hudson, & Mogg (2007) define initial attentional bias as the direction of the initial shift of gaze when two or more pictures are presented simultaneously, and maintained attentional bias as the duration of gaze on the pictures. In addition, in a review paper, Field and Cox (2008) stated that individuals can make only one shift of attention toward one of the stimuli in a short exposure duration, whereas in a longer exposure duration individuals can make multiple shifts of attention between stimuli. They stated that in addiction literature generally initial attentional bias has been assessed with a short duration between 50 and 200 ms and maintained attentional bias has been measured with a longer duration between 500 and 2000 ms. Thus, based on the previous studies mentioned above, this study involved pictures with exposure durations of 200ms for initial attentional bias and 1000ms for maintained attentional bias.

Each trial began with a central black fixation cross on a white background for 1000 ms, followed by a pair of images, which were presented for either 200ms (initial attention) or 1000ms (maintained attention). After 5 practice trials, 60 critical trials were displayed. Each block contained 2 buffer trials and 60 images: 20 critical pairs (chocolate/neutral images) for 200ms, 20 critical pairs (chocolate/neutral images) for 1000ms, 20 filler pairs (neutral/neutral
images) of 200 and 1000ms, side by side, but randomly displayed on the left or right. The individual images used are shown in Appendix 7. The chocolate images consisted of a commonly available range of types to increase relevance for all subjects and neutral images were non-emotional and non-food items (e.g., office supplies). The images were considered for their shape, size, and luminescence before matching as a pair. After the pair of images disappeared, a 2 mm wide black dot probe appeared behind where one of the images had been. These were defined as a congruent or incongruent location if they appeared behind a chocolate or neutral image respectively. The participants were required to respond as quickly as possible to the probe by pressing the corresponding keys labelled (Z) for left and (M) for right on the computer keyboard. The dot probe was displayed until a response was made. Participants were instructed as follows: “At the beginning of each trial you should look at a black cross in the centre of the screen. This will be replaced by a pair of pictures on the screen for a brief moment. When the pictures disappear a black dot will appear on either the left or right hand side of the screen. When you see this dot you should respond as quickly as possible by pressing either the Z (for left) or M (for right) key (point to them). When you have responded, the black cross will again appear in the centre of the screen, and it is very important that you focus on this before the next pair of pictures is presented.” Reaction time and errors performed were collected using E-Prime software.

In line with previous research (Bradley et al., 2004), mean reaction time (RT) to probes was analysed only for trials in which there were correct responses and for responses that were greater than 200 ms and less than 2000 ms after the disappearance of the image. The trials were also excluded if they were 2SD above or below the mean. Attentional bias was calculated by subtracting the mean RT in trials where the probe was congruent (ie, replaced chocolate pictures) from the mean RT in trials where the probe was incongruent (ie, replaced neutral pictures). Attentional bias was calculated for initial attentional bias (when image exposure duration was 200ms), maintained attentional bias (when image exposure duration was 1000ms), and total attentional bias (200ms + 1000ms). Positive attentional bias scores indicate greater visual vigilance for chocolate-related pictures.

Subjective cravings, hunger, and affect. To assess state hunger and cravings, the following measures were used (see Appendix 6): a single item of hunger (i.e., “how hungry are you at the moment?”) using a 100mm (0-100) Visual Analogue Scale (VAS) (Tapper et al, 2010); a single item of chocolate craving using a 100mm (0-100) VAS (i.e., “How much do you crave chocolate at this very moment?”) (Smeets, Roefs, & Jansen, 2009); and chocolate cravings using 3 items (i.e., the 1st factor of FCCQ-S: an intense desire to consume chocolate) from FCCQ-S (Cepeda-Benito et al., 2000b) (i.e., “I have an intense desire to eat a snack”, “I’m craving a snack”, and “I have an urge for snacking”) were used at the time points mentioned
above. Response format involved a 5-point scale (i.e., 1 == ‘strongly agree’ to 5 = ‘strongly disagree’). The individual scores of these three items of FCCQ-S added up to provide the total score of desire to snack, with total score range 3 to 15.

Affect was assessed using the 11-point Feeling Scale (Hardy & Rejeski, 1989) from -5 to +5, low to high feeling of pleasure, and the 6-point Felt Arousal Scale (Svebak & Murgatroyd, 1985) from 1 to 6, low to high feeling of activation/arousal. Both measures have been widely used to assess affective responses to acute exercise.

_Time to next event._ The time from leaving the laboratory session to the next chocolate consumption was calculated from the time of a text message sent from the participant’s mobile phone. The similar way of measuring time to next eating the next snack was used in previous research (Thayer et al., 1993).

**4.2.4. Data analysis**

SPSS (version 18) was used to analyse the data. Descriptive statistics were used to describe the participant’s demographic data. As a manipulation check, dependent t-tests were used to check for expected differences in HR between treatments. The mean (SD) RPE and HRR during exercise were calculated. Baseline values for subjective measures were the mean of pre-post the first dot probe task after conducting a t-test to confirm no change. After confirming that there was no significant change in subjective measures from pre-post the first dot probe task, we calculated the mean of those measures to create a more stable average baseline score.

First of all, baseline values for attentional bias and self-reported craving were compared using a one-way ANOVA by groups (normal weight x overweight-temporarily abstinent x Lent) to identify possible group differences prior to each treatment sessions. Next, the outcomes were analysed in a 3-way mixed ANOVA to identify main and interaction effects of group (3 levels: normal weight, overweight-temporarily abstinent, Lent) (between subject) x condition (2 levels: exercise, rest) (within subject) x time (as described above) (within subject). The analysis plan was that if there were no main group effects or group interaction effects with condition or time in either step, the main and interactive effects of condition and time on the respective outcomes (ie, self-reported cravings, hunger, attentional bias measures and impulsivity) would be analysed with a 2-way ANOVA, with and without various covariates including baseline measures (e.g., BMI, trait measures). Three-way ANOVAs with order were carried out to determine if there were any learning effects.
Initially Pearson correlation analyses were carried out to determine if the main outcomes (attentional bias and subjective outcomes) were associated with scores from background and trait measures, or if the outcome differences between exercise and passive conditions were associated with trait measures. Any variables that were associated were considered as covariates in ANCOVAs to extend the ANOVAs in subsequent analyses.

For analyses involving attentional bias data, fully repeated 2-way ANOVAs were conducted to determine main and interaction effects of time (pre and post-treatment) and condition (exercise and rest). For analyses involving self-reported measures of cravings, hunger, and affect fully repeated 2-way ANOVAs were conducted, to determine main and interactive effects of condition (exercise, rest) × time (5 levels: baseline, mid-treatment, immediately post-treatment, after 2nd dot probe task, and 5 minutes after the task). The delayed time for the next chocolate consumption was analysed with a one-way ANOVA. If the data were not normally distributed a Wilcoxon Signed Ranks test was carried out. If there was no effect of condition on the delayed time, the plan was for participants to be categorised to 3 groups: 1) those eating immediately after test; 2) 1-60mins after; 3) more than 60mins after and then valid percentage would be provided.

In analyses involving either attentional bias or self-reported measures where there was a significant interaction effect, post hoc paired t-tests were conducted to determine post treatment differences between conditions and also changes from pre-treatment to subsequent assessments, for both conditions. A value of $p < 0.05$ was used to determine statistical significance with a 2-tailed test and Bonferroni correction was applied when multiple t-tests were administered. Cohens $d$ values were reported to show effect sizes. If there were significant effects of condition on self-reported cravings or attentional bias, as suggested by Cerin (2010) and Baron and Kenny (1986), regression analyses were performed to determine the mediating effects of affect using measures of attentional bias or cravings at baseline and mid or post-exercise, and change in affect from pre-mid or post-exercise (see Figure 4.3).

**Figure 4.3.** Hypothesised path model for mediation analyses

Finally, correlation analyses were carried out to examine the relationship between attentional bias measures and subjective measures for cravings, between subjective measures (cravings and
hunger), and between outcome measures and impulsivity measures. Structured qualitative data on attribution for chocolate snacking was summarised by categorising responses in terms of 6 variables (i.e., FAS, FS, Cues, Hunger, Craving, and Social gathering) based on the factors commonly mentioned in previous studies (Herman & Polivy, 2004; Thayer, 2001).

4.3. Results

4.3.1. Baseline participant characteristics by group sampled

Demographic data for 58 participants (20 normal weight – temporarily abstinent (TA), 21 overweight -TA, and 17 Lent) are shown in Table 4.1. As expected, BMI was significantly different among the three groups ($F(2, 55) = 41.20, p < 0.001$). In general, the three groups had similar eating and food-related characteristics. However, there were group differences in eating behaviour (e.g., emotional eating in TFEQ-18 ($F(2, 55) = 5.64, p < 0.01$), food present score in PFS ($F(2, 55) = 3.44, p < 0.05$, and FCCQ-T ($F(2, 55) = 5.04, p = 0.01$)). Emotional eating was significantly higher in the TA overweight group than the TA normal weight group, $t(39) = -3.68, p = 0.001$. Trait chocolate craving score was significantly higher in the TA overweight group, $t(39) = -2.87, p = 0.007$, and the Lent group, $t(35) = -2.74, p = 0.01$, compared with the TA normal weight group. From personal diaries received before the experimental sessions, the change scores in FAS from pre to post chocolate consumption was significantly larger in the normal weight-TA group than the overweight-TA group, $t(39) = 3.08, p < 0.01$, suggesting that the former experienced a greater increase in affective activation from eating chocolate.

The average baseline means (SD) on the main outcome variables for the three groups is shown in Table 4.2.
Table 4.1. Participant demographics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean (SD) score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal weight -TA (N=20)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>23.90 (6.87)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.44 (1.88)c</td>
</tr>
<tr>
<td>TFEQ-181</td>
<td></td>
</tr>
<tr>
<td>Cognitive restraint</td>
<td>14.75 (3.81)</td>
</tr>
<tr>
<td>Uncontrolled eating</td>
<td>21.50 (4.53)</td>
</tr>
<tr>
<td>Emotional eating</td>
<td>7.30 (1.72)a</td>
</tr>
<tr>
<td>Impulsivity (BIS-11)</td>
<td></td>
</tr>
<tr>
<td>Attentional Impulsiveness</td>
<td>17.70 (2.70)</td>
</tr>
<tr>
<td>Motor Impulsiveness</td>
<td>26.40 (5.63)</td>
</tr>
<tr>
<td>Nonplanning</td>
<td>26.65 (4.25)</td>
</tr>
<tr>
<td>Hedonic Hunger (PFS)²</td>
<td></td>
</tr>
<tr>
<td>Food Available</td>
<td>2.42 (0.98)</td>
</tr>
<tr>
<td>Food Present</td>
<td>3.19 (0.83)</td>
</tr>
<tr>
<td>Food Tasted</td>
<td>2.92 (0.91)</td>
</tr>
<tr>
<td>Trait chocolate craving (FCCQ-T)</td>
<td>108.70 (24.71)</td>
</tr>
<tr>
<td>Physical activity (min/week)</td>
<td></td>
</tr>
<tr>
<td>Moderate exercise</td>
<td>320.00 (155.36)</td>
</tr>
<tr>
<td>Vigorous exercise</td>
<td>105.40 (137.59)</td>
</tr>
<tr>
<td>Sleeping hours (per day)</td>
<td>7.23 (1.46)</td>
</tr>
<tr>
<td>Daily EE² (kcal/kg/wk/d)</td>
<td>338.80 (184.08)</td>
</tr>
<tr>
<td>Chocolate consumption for 3dys</td>
<td>329.00 (67.52)</td>
</tr>
<tr>
<td>Δ FS³</td>
<td>1.53 (0.60)</td>
</tr>
<tr>
<td>ΔFAS³</td>
<td>1.49 (0.48)a</td>
</tr>
</tbody>
</table>

Note. TA = Temporarily abstinent

¹ TFEQ-R 18. Theoretical range: cognitive restraint (6-24), uncontrolled eating (9-36), emotional eating (3-12).
² Power of Food Scale (PFS). Average of item scores.
³ Daily EE = daily energy expenditure (kcal/kg/wk/d)
⁴ ΔFS / ΔFAS. Mean (SD) of change scores of feeling scale and felt arousal scale (from pre to post chocolate consumption) during 3 days of chocolate consumption. Scores from a 3 day-chocolate diary (see Appendix 5).

* Significant difference (with Bonferroni correction, p < 0.01).

** Significant difference (with Bonferroni correction, p < 0.01).

*** Significant difference between (with Bonferroni correction, , p < 0.01).
Table 4.2. Baseline (SD) for the outcome variables by group sampled

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Normal weight N=20</th>
<th>Overweight N=21</th>
<th>Lent N=17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attentional bias (msec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13.27 (26.41)</td>
<td>23.76 (43.90)</td>
<td>13.39 (26.32)</td>
</tr>
<tr>
<td>Initial</td>
<td>14.69 (50.03)</td>
<td>18.27 (40.46)</td>
<td>14.66 (34.72)</td>
</tr>
<tr>
<td>Maintained</td>
<td>10.46 (29.75)</td>
<td>32.86 (67.67)</td>
<td>10.78 (40.63)</td>
</tr>
<tr>
<td>Chocolate craving (VAS)</td>
<td>46.46 (23.10)</td>
<td>39.99 (29.73)</td>
<td>54.09 (25.06)</td>
</tr>
<tr>
<td>Hunger (VAS)</td>
<td>45.59 (22.99)</td>
<td>31.72 (26.14)</td>
<td>39.53 (30.14)</td>
</tr>
<tr>
<td>Desire to eat chocolate (FCCQ-S)</td>
<td>9.93 (2.11)</td>
<td>9.33 (2.82)</td>
<td>10.94 (7.92)</td>
</tr>
<tr>
<td>FS</td>
<td>2.47 (1.47)</td>
<td>2.08 (1.41)</td>
<td>2.77 (1.42)</td>
</tr>
<tr>
<td>FAS</td>
<td>3.33 (1.14)</td>
<td>3.19 (1.09)</td>
<td>3.86 (1.24)</td>
</tr>
<tr>
<td>Resting HR (bpm)</td>
<td>74.56 (9.86)</td>
<td>77.43 (9.19)</td>
<td>72.97 (12.14)</td>
</tr>
</tbody>
</table>

Note. ¹ Total attentional bias = initial attentional bias (200ms) + maintained attentional bias (1000ms); VAS on 0 to 100 scale; FCCQ-S on 3 to 15 scale; FS on -5 to +5 scale; FAS on 1 to 6 scale; HR – Heart Rates.

Baseline scores for subjective measures were calculated by the mean of pre (T1) and post (T2) the 1st visual dot probe task as there was no difference between the two time points. In attentional bias reaction time (RT) data, 1.7% of data had errors (i.e., incorrect responses) and 4.3% of data were outliers (i.e., when RT was < 200ms, > 2000ms, and the mean RT ± 2SD) and these data were excluded. The range of baseline AB scores across participants was from 10.46 ms to 32.86 ms (AB = 0 means participants looked at chocolate images and neutral images equally; AB > 0 means participants were more likely to be looking at chocolate images; AB < 0 means participants were more likely to be looking at neutral images). Overall, results revealed that there were no significant differences between groups at baseline for any of the outcome variables.

4.3.2. Manipulation checks

The mean heart rate (HR), rating of perceived exertion (RPE) score, and the percentage of heart rate reserve for three groups during exercise are shown in Table 4.3. ANOVAs revealed that there were no differences between groups suggesting that all groups exercised at a similar intensity. The overall mean HR and RPE scores during exercise were 123.07 bpm (14.70) and 12.51 (0.47), respectively. The overall mean of % of HRR was 43.87 (12.77). The results fell
within the range of intensities of moderate exercise suggested by the American College of Sports Medicine (2009), and within the target range of 11 – 13 on the RPE scale.

Table 4.3. Mean (SD) for HR, RPE, and HRR

<table>
<thead>
<tr>
<th>Variables</th>
<th>Normal weight N=20</th>
<th>Overweight N=21</th>
<th>Lent N=17</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (bpm)</td>
<td>121.83 (14.89)</td>
<td>128.51 (13.83)</td>
<td>117.81 (14.05)</td>
</tr>
<tr>
<td>RPE</td>
<td>12.59 (0.34)</td>
<td>12.55 (0.45)</td>
<td>12.38 (0.60)</td>
</tr>
<tr>
<td>HRR (%)</td>
<td>41.09 (11.51)</td>
<td>51.22 (13.33)</td>
<td>38.05 (9.20)</td>
</tr>
</tbody>
</table>

4.3.3. Effects of exercise on attentional bias and chocolate cravings by three sampled groups

A 3-way mixed ANOVA, 3 (group: TA normal weight, TA overweight, and Lent) × 2 (condition: exercise and passive) × 2 (time: pre and post-treatment), revealed that there were no significant three-way group interactive effects with condition and time for total attentional bias ($F(2, 55) = 1.33$), initial attentional bias ($F(2, 55) = 0.14$), and maintained attentional bias ($F(2, 55) = 0.77$), with $p > 0.05$. A 3-way mixed ANOVA, 3 (group) × 2 (condition) × 5 (time: baseline, mid-treatment, post-treatment, after visual dot probe task, and at 5 minutes after the task) also showed that there were no significant three-way group interactive effects with condition and time for chocolate craving ($F(8, 220) = 0.51$), hunger ($F(8, 220) = 0.93$), and desire to eat chocolate ($F(8, 220) = 1.84$), with $p > 0.05$. To sum up, there were no main and interaction effects of group × condition × time on attentional bias and subjective measures. Thus, as planned, the main and interactive effects of condition and time for each outcome will be analysed in the following section, with data from all 3 groups combined.

4.3.4. Effects of condition order on baseline outcome values

A 3-way mixed ANOVA, 2 (order) × 2 (condition) × 2 (time: pre and post-treatment) for attentional bias / 5 (time: time: baseline, mid-treatment, post-treatment, after visual dot probe task, and at 5 minutes after the task) for subjective measures, revealed that session order did not interact with any outcome variables, $p > 0.05$ (see Table 4.4).
**Table 4.4.** The effects of session order on outcome variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Order x Condition</th>
<th>Order x Time</th>
<th>Order x Condition x Time Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attentional bias</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$F(1, 56) = 0.02$</td>
<td>$F(1, 56) = .034$</td>
<td>$F(1, 56) = 1.08$</td>
</tr>
<tr>
<td>Initial</td>
<td>$F(1, 56) = 0.23$</td>
<td>$F(1, 56) = 0.12$</td>
<td>$F(1, 56) = 0.23$</td>
</tr>
<tr>
<td>Maintained</td>
<td>$F(1, 56) = 0.06$</td>
<td>$F(1, 56) = 0.28$</td>
<td>$F(1, 56) = 0.90$</td>
</tr>
<tr>
<td>Chocolate craving (VAS)</td>
<td>$F(1, 56) = 1.71$</td>
<td>$F(2.38, 133.11) = 0.18$</td>
<td>$F(2.33, 130.73) = 0.04$</td>
</tr>
<tr>
<td>Hunger (VAS)</td>
<td>$F(1, 56) = 1.76$</td>
<td>$F(2.61, 146.21) = 0.41$</td>
<td>$F(2.90, 162.21) = 0.42$</td>
</tr>
<tr>
<td>Desire to eat chocolate</td>
<td>$F(1, 56) = 0.23$</td>
<td>$F(1.60, 89.48) = 0.26$</td>
<td>$F(1.51, 84.67) = 0.44$</td>
</tr>
<tr>
<td>FS</td>
<td>$F(1, 56) = 0.02$</td>
<td>$F(3.06, 171.50) = 0.48$</td>
<td>$F(2.88, 161.01) = 1.87$</td>
</tr>
<tr>
<td>FAS</td>
<td>$F(1, 56) = 1.85$</td>
<td>$F(3.27, 183.35) = 0.22$</td>
<td>$F(2.92, 163.28) = 1.21$</td>
</tr>
</tbody>
</table>

### 4.3.5. Correlations between background and trait measures with the outcome measures

Table 4.5 shows the correlation between baseline outcome measures and trait measures by condition. For the analysis, the total score for each trait measure was reported as there were no different findings in the analyses involving the subscale scores. In the passive condition, baseline attentional bias scores were not correlated with any trait measures. Subjective hunger and desire were negatively correlated with BMI and subjective craving was significantly positively correlated with PFS. In the exercise condition, baseline total attentional bias was positively correlated with FCCQ-T. Subjective craving and hunger was negatively correlated with BMI and craving was positively correlated with PFS.

The correlation between a calculated difference value in outcomes post-treatment and trait measures are reported in Table 4.6. Also, the changes in FS and FAS from pre-post exercise were calculated and correlations with trait measures are shown in Table 4.6. There was no significant relationship between outcome measures after treatment and trait measures.
### Table 4.5. Baseline correlations between outcome measures and background and trait measures by condition

<table>
<thead>
<tr>
<th>Exercise condition</th>
<th>T-AB</th>
<th>I-AB</th>
<th>M-AB</th>
<th>Craving</th>
<th>Hunger</th>
<th>Desire</th>
<th>BMI</th>
<th>EE/d</th>
<th>GNG</th>
<th>BIS</th>
<th>PFS</th>
<th>TFEQ</th>
<th>FCCQT</th>
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</thead>
<tbody>
<tr>
<td>T-AB</td>
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<td>I-AB</td>
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<tr>
<td>TFEQ</td>
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<tr>
<td>FCCQT</td>
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</tr>
</tbody>
</table>

* * p < 0.05  
** ** p < 0.01

Note. T-AB = Total attentional bias; I-AB = Initial attentional bias; M-AB = maintained attentional bias; Craving = 100mm VAS; Hunger = 100mm VAS; Desire = from FCCQ-S; BMI = Body Mass Indec; EE/d = daily energy expenditure; GNG = Go/No-go task (trait impulsivity); BIS = sum of the Barratt Impulsiveness Scale (attentional impulsiveness + motor impulsiveness + nonplanning impulsiveness); PFS = sum of Power of Food Scale (food available + food present + food tasted); TFEQ = sum of Three-Factor Eating Questionnaire-R18 (cognitive restraint + uncontrolled eating + emotional eating); FCCQT = sum of the Food Chocolate-Craving Questionnaire Trait
### Table 4.6. Correlation between outcome measures and trait measure after treatment

<table>
<thead>
<tr>
<th></th>
<th>AB-T</th>
<th>AB-I</th>
<th>AB-M</th>
<th>Craving</th>
<th>Hunger</th>
<th>Desire</th>
<th>∆FS</th>
<th>∆FAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>0.02</td>
<td>0.05</td>
<td>0.01</td>
<td>0.10</td>
<td>0.04</td>
<td>-0.04</td>
<td>-0.20</td>
<td>-0.06</td>
</tr>
<tr>
<td>EE/d</td>
<td>-0.11</td>
<td>0.00</td>
<td>-0.14</td>
<td>-0.11</td>
<td>-0.18</td>
<td>-0.24</td>
<td>0.25</td>
<td>0.00</td>
</tr>
<tr>
<td>GNG</td>
<td>0.10</td>
<td>-0.01</td>
<td>0.21</td>
<td>0.04</td>
<td>0.16</td>
<td>-0.06</td>
<td>-0.13</td>
<td>-0.21</td>
</tr>
<tr>
<td>BIS</td>
<td>-0.14</td>
<td>-0.11</td>
<td>-0.08</td>
<td>0.08</td>
<td>-0.02</td>
<td>-0.03</td>
<td>0.14</td>
<td>-0.12</td>
</tr>
<tr>
<td>PFS</td>
<td>-0.16</td>
<td>-0.19</td>
<td>-0.08</td>
<td>-0.04</td>
<td>-0.19</td>
<td>-0.09</td>
<td>0.22</td>
<td>-0.02</td>
</tr>
<tr>
<td>TFEQ</td>
<td>-0.10</td>
<td>-0.09</td>
<td>-0.13</td>
<td>-0.19</td>
<td>-0.20</td>
<td>-0.04</td>
<td>-0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>FCCQT</td>
<td>-0.14</td>
<td>-0.19</td>
<td>-0.10</td>
<td>0.01</td>
<td>-0.10</td>
<td>-0.01</td>
<td>-0.06</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Note. ‘AB–T’ = Differences between exercise and passive condition in total attentional bias; ‘AB–I’ = Differences between exercise and passive condition in initial attentional bias; ‘AB–M’ = Differences between exercise and passive condition in maintained attentional bias; ‘Craving’ = Differences between exercise and passive condition in Craving (VAS); ‘Hunger’ = Differences between exercise and passive condition in Hunger (VAS); ‘Desire’ = Differences between exercise and passive condition in Desire (FCCQ-S); ∆FS = change score of feeling scale (T3-T1); ∆FAS = change score of felt arousal scale (T3-T1); EE/d = daily energy expenditure; GNG = Go/No-go task (trait impulsivity); BIS = sum scores of BIS; PFS = sum scores of PFS; TFEQ = sum scores of TFEQ; FCCQT = sum scores of trait chocolate craving.

Correlation analyses were further carried out to determine the relationship between a state measure (Go/No-go task) of impulsivity, a subjective trait measure (BIS-11), and measures of chocolate craving. The results showed that state impulsivity (RT) was significantly correlated with non-planning impulsiveness (one of three subscales in BIS-11) ($r = -0.29$, $p < 0.03$), but not with attentional impulsiveness and motor impulsiveness ($p > 0.05$). There were no significant correlations between impulsivity measures and subjective cravings at baseline as shown in Table 4.5 and 4.6.

Based on the correlation results reported above, trait measures will be regarded as covariates in the following analysis.

4.3.6. Effect of exercise on attentional bias

**Total attentional bias**

For total attentional bias there were significant main effects of condition and time and an interactive effect of condition × time as shown in Figure 4.4 and Table 4.7.
Figure 4.4. Mean (SEM) total attentional bias over time by condition

Table 4.7. Mean (SD), and main and interactive effects of condition and time for attentional bias

<table>
<thead>
<tr>
<th>Variable (Time)</th>
<th>Condition</th>
<th>Effect (main, interaction)</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passive control</td>
<td>Exercise</td>
<td>(1) condition</td>
</tr>
<tr>
<td>Total AB</td>
<td>Baseline</td>
<td>18.97 (38.54)</td>
<td>15.23 (30.55)</td>
</tr>
<tr>
<td></td>
<td>Post-treatment</td>
<td>34.46 (54.20)</td>
<td>14.73 (26.63)</td>
</tr>
<tr>
<td>Initial AB</td>
<td>Baseline</td>
<td>14.97 (44.27)</td>
<td>16.99 (39.91)</td>
</tr>
<tr>
<td></td>
<td>Post-treatment</td>
<td>35.75 (52.94)</td>
<td>15.88 (37.91)</td>
</tr>
<tr>
<td>Maintained AB</td>
<td>Baseline</td>
<td>24.11 (62.14)</td>
<td>13.20 (41.38)</td>
</tr>
<tr>
<td></td>
<td>Post-treatment</td>
<td>34.29 (60.20)</td>
<td>12.94 (32.67)</td>
</tr>
</tbody>
</table>

* $p < 0.05$

Note. AB – attentional bias

Post hoc paired sample t-tests (with Bonferroni correction) showed that there was no baseline difference between conditions, $t(57) = 0.64, p > 0.05$. Total attentional bias after treatment was significantly larger in the passive condition, compared with exercise condition, $t(57) = 2.79, p < 0.01$ (95% CI 5.59 to 33.88, ES $d = 0.42$). In the passive condition total attentional bias significantly increased after treatment compared to baseline, $t(57) = -2.58, p = 0.013$, with no change in the exercise condition. The mean (SD) of the change scores of total attentional bias (from pre - post treatment) were 15.49 (45.77) in the passive condition and -0.51 (28.57) in exercise condition.
Further analyses were carried out by adding FCCQ-T as a covariate based on the previous correlation analysis findings (see Table 4.5). This had no impact on the reported main and interactive effect of condition and time for the attentional bias measures.

**Initial attentional bias**

There was a significant main effect of time and interactive effect of condition × time, as shown in Figure 4.5 and Table 4.7.

![Figure 4.5. Mean (SEM) initial attentional bias over time by condition](image)

**Maintained attentional bias**

A significant main effect of condition was shown for maintained attentional bias, with no significant main effect of time or interactive effect of condition × time (see Figure 4.6 and Table 4.7). Although there was no significant condition × time, I conducted exploratory Post hoc paired t-tests (with Bonferroni correction). There was no baseline difference between conditions, \( t(57) = -0.29, p > 0.05 \). Maintained attentional bias was significantly larger in the passive condition compared with baseline, \( t(57) = -2.84, p < 0.01 \) (95% CI -35.43 to -6.14, ES \( d = 0.42 \)). The mean (SD) of the change scores of initial attentional bias were 20.78 (55.69) in the passive condition and -1.11 (42.54) in the exercise condition.
The changes from baseline to post-treatment in both conditions were not significantly different. The mean (SD) of the change scores of maintained attentional bias were 10.18 (68.36) in the passive condition and -0.26 (50.63) in exercise condition.

**Figure 4.6.** The effects of a passive and exercise condition on maintained attentional bias

**4.3.7. Effects of exercise on self-reported craving and affect**

Fully repeated 2-way ANOVAs, 2 (condition: exercise and passive) × 5 (time: baseline, mid-, post-treatment, after dot probe task, at 5 min after the task) were conducted to examine the effects of exercise on subjective cravings, hunger, and affect (see Table 4.8).

*Chocolate craving (VAS)*

There were significant main effects of condition and time and interactive effect of condition × time, with Greenhouse-Geisser correction, as shown in Figure 4.7 and Table 4.8.

Post hoc t-tests (with Bonferroni correction) revealed that there was no baseline difference between conditions, \( t(57) = -0.35, p > 0.05 \). There was a significant difference in chocolate craving between the passive and exercise conditions at immediately post-treatment (\( t(57) = 3.67, p = 0.001, 95\% \) CI 7.26 to 24.67, ES \( d = 0.54 \)), after the dot probe task (\( t(57) = 3.76, p < 0.001, 95\% \) CI 7.77 to 25.51, ES \( d = 0.55 \)) and 5min after the task (\( t(57) = 4.15, p < 0.001, 95\% \) CI 8.69 to 24.90, ES \( d = 0.57 \)). In the exercise condition, chocolate craving was significantly lower at mid-treatment (\( t(57) = 4.68, p < 0.001 \)), immediately post-treatment (\( t(57) = 5.26, p < 0.001 \)), after the dot probe task (\( t(57) = 4.68, p = 0.001 \)), and 5min after the task (\( t(57) = 4.11, p < 0.001 \)), compared to baseline. In the passive condition, no change was shown from baseline to follow-up assessment. The mean (SD) of the change scores for craving (by subtracting post-
Table 4.8. Mean (SD), and main, and interactive effects of condition and time for subjective measures

<table>
<thead>
<tr>
<th>Variable (Time)</th>
<th>Condition</th>
<th>Effect (main, interaction)</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chocolate craving (VAS)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>Passive control</td>
<td>45.86 (25.23)</td>
<td>46.84 (27.64)</td>
</tr>
<tr>
<td>(2)</td>
<td>Exercise</td>
<td>41.38 (28.58)</td>
<td>31.62 (29.89)</td>
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<tr>
<td>(3)</td>
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<td>42.90 (29.52)</td>
<td>26.93 (29.89)</td>
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<tr>
<td>(4)</td>
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<td>51.05 (29.05)</td>
<td>34.41 (31.20)</td>
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<td>(5)</td>
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<td>50.95 (29.54)</td>
<td>34.16 (29.33)</td>
</tr>
<tr>
<td>Desire to eat chocolate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>Passive control</td>
<td>10.41 (7.29)</td>
<td>9.60 (2.60)</td>
</tr>
<tr>
<td>(2)</td>
<td>Exercise</td>
<td>9.38 (2.93)</td>
<td>7.97 (3.38)</td>
</tr>
<tr>
<td>(3)</td>
<td></td>
<td>10.09 (3.15)</td>
<td>7.33 (3.68)</td>
</tr>
<tr>
<td>(4)</td>
<td></td>
<td>10.76 (3.00)</td>
<td>8.81 (3.57)</td>
</tr>
<tr>
<td>(5)</td>
<td></td>
<td>11.07 (2.92)</td>
<td>9.17 (3.02)</td>
</tr>
<tr>
<td>Hunger (VAS)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>Passive control</td>
<td>38.66 (27.21)</td>
<td>38.92 (26.24)</td>
</tr>
<tr>
<td>(2)</td>
<td>Exercise</td>
<td>42.69 (27.93)</td>
<td>34.38 (29.12)</td>
</tr>
<tr>
<td>(3)</td>
<td></td>
<td>45.41 (30.13)</td>
<td>32.07 (31.41)</td>
</tr>
<tr>
<td>(4)</td>
<td></td>
<td>48.50 (31.40)</td>
<td>38.50 (31.38)</td>
</tr>
<tr>
<td>(5)</td>
<td></td>
<td>50.78 (31.84)</td>
<td>42.40 (30.73)</td>
</tr>
<tr>
<td>FS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>Passive control</td>
<td>2.29 (1.48)</td>
<td>2.53 (1.40)</td>
</tr>
<tr>
<td>(2)</td>
<td>Exercise</td>
<td>1.97 (1.52)</td>
<td>2.57 (1.38)</td>
</tr>
<tr>
<td>(3)</td>
<td></td>
<td>2.00 (1.49)</td>
<td>3.29 (1.23)</td>
</tr>
<tr>
<td>(4)</td>
<td></td>
<td>2.21 (1.48)</td>
<td>3.02 (1.15)</td>
</tr>
<tr>
<td>(5)</td>
<td></td>
<td>2.16 (1.60)</td>
<td>2.76 (1.39)</td>
</tr>
<tr>
<td>FAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>Passive control</td>
<td>3.28 (1.17)</td>
<td>3.58 (1.17)</td>
</tr>
<tr>
<td>(2)</td>
<td>Exercise</td>
<td>2.71 (1.12)</td>
<td>4.29 (1.03)</td>
</tr>
<tr>
<td>(3)</td>
<td></td>
<td>2.71 (1.12)</td>
<td>4.50 (1.16)</td>
</tr>
<tr>
<td>(4)</td>
<td></td>
<td>3.16 (1.14)</td>
<td>4.00 (1.19)</td>
</tr>
<tr>
<td>(5)</td>
<td></td>
<td>2.90 (1.28)</td>
<td>3.38 (1.15)</td>
</tr>
</tbody>
</table>

* p < 0.05; ** p < 0.01; *** p < 0.001

Note. (1) = baseline; (2) = mid-treatment; (3) = post-treatment; (4) = after dot probe task; (5) = at 5min after the task; VAS = Visual Analogue Scale on 0 to 100 scale; Desire to eat chocolate = FCCQ-S on 3 to 15 scale; FS = Feeling Scale on -5 to + 5 scale; FAS = Felt Arousal Scale on 1 to 6 scale.
treatment craving from baseline craving) were -2.96 (20.70) in the passive condition and -19.91 (28.82) in the exercise condition.

Note. Time 1 = baseline; 2 = mid-treatment; 3 = immediately post-treatment; 4 = after 2nd dot probe task; 5 = at 5min after the task

**Figure 4.7.** Mean (SEM) chocolate craving over time by condition

*Desire to eat chocolate*

The effects of exercise on desire to eat chocolate are shown in Figure 4.8 and Table 4.8. There were significant main effects of condition and time, but no significant interaction effect.

Note. Time 1 = baseline; 2 = mid-treatment; 3 = immediately post-treatment; 4 = after 2nd dot probe task; 5 = at 5min after the task

**Figure 4.8.** Mean (SEM) desire to eat chocolate over time by condition

Paired sample t-tests revealed that no baseline difference was shown between conditions, $t(57) = 0.83, p > 0.05$. There was a significant difference in mean desire to eat chocolate between the
passive and the exercise conditions at post-treatment ($t(57) = 4.50, p < 0.001, 95\%\ CI\ 1.53\ to\ 3.98,\ ES\ d = 0.80$), after the dot probe task ($t(57) = 3.56, p = 0.001, 95\%\ CI\ 0.85\ to\ 3.04,\ ES\ d = 0.59$), and 5min after the task ($t(57) = 3.80, p < .001, 95\%\ CI\ 0.90\ to\ 2.90,\ ES\ d = 0.64$). In the exercise condition, desire to eat chocolate was significantly lower than baseline at mid-treatment ($t(57) = 4.30, p < 0.001$), and post-treatment ($t(57) = 5.27, p < 0.001$). There were no significant changes in desire to eat chocolate in the passive condition over time. The mean (SD) of the change scores of desire (by subtracting post-treatment desire from baseline desire) were 6.76 (13.47) in the passive condition and -6.85 (24.11) in the exercise condition.

**Hunger (VAS)**

Figure 4.9 and Table 4.8 show a significant main effect of time and interactive effect of condition $\times$ time. Post hoc paired sample t-tests (with Bonferroni correction) revealed that no baseline difference was shown between conditions, $t(57) = -0.07, p > 0.05$, and there was a significant difference between the exercise and the passive condition only at immediately post-treatment ($t(57) = 2.74, p = 0.008$). In the passive condition, hunger was significantly increased at immediately post-treatment ($t(57) = -3.82, p < 0.001$), after the dot probe task ($t(57) = -4.55, p < 0.001$), and 5min after the task ($t(57) = -5.11, p < 0.001$), compared to baseline. However, at follow-up hunger in the exercise condition did not significantly differ from baseline. The mean (SD) of the change scores of hunger (by subtracting post-treatment hunger from baseline hunger) were 6.76 (13.47) in the passive condition and -6.85 (24.11) in the exercise condition.

![Figure 4.9. Mean (SEM) hunger over time by condition](image-url)
Self-reported chocolate consumption after the session

The mean (SD) of the delayed time after the passive condition was 211.20 (588.31) mins (with range 0 to 2880 mins) and after the exercise condition was 196.90 (443.35) mins (with range 0 to 2160 mins). The data were not normally distributed [Skewness: passive = 3.59 (SE 0.37); exercise = 3.58 (0.37); Kurtosis: passive = 12.88 (0.72); exercise = 13.05 (0.72)]. Thus, Wilcoxon Signed Ranks test was carried out and the results showed that there was no significant difference between exercise and passive condition ($z = -1.73$, $p = 0.07$). However, when the participants were categorised into the 3 time periods shown in Table 4.9, fewer people who did exercise appeared to eat the next chocolate immediately after the exercise session (10%) compared with 32% after the passive condition.

Table 4.9. The percentage of subjects for the next chocolate consumption

<table>
<thead>
<tr>
<th>Time</th>
<th>Passive (%)</th>
<th>Total N (41)</th>
<th>Exercise (%)</th>
<th>Total N (41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediately after test</td>
<td>31.7</td>
<td>13</td>
<td>9.8</td>
<td>4</td>
</tr>
<tr>
<td>1 - 60mins</td>
<td>39.0</td>
<td>16</td>
<td>46.3</td>
<td>19</td>
</tr>
<tr>
<td>&gt; 61mins</td>
<td>29.3</td>
<td>12</td>
<td>43.9</td>
<td>18</td>
</tr>
</tbody>
</table>

Affect

A fully repeated ANOVA revealed significant main effects of condition and time, and interactive effect of condition × time for FS (see Figure 4.10 and Table 4.8).

![Figure 4.10. Mean (SEM) FS over time by condition](image)

Note. Time 1 = baseline; 2 = mid-treatment; 3 = immediately post-treatment; 4 = after 2nd dot probe task; 5 = at 5min after the task
Post hoc paired sample t-tests showed that no baseline difference was shown between conditions, $t(57) = -1.19$, $p > 0.05$. There were significant differences between the exercise and the passive condition in FS at post-treatment ($t(57) = -5.81$, $p < 0.001$, 95% CI -1.74 to -0.85, ES $d = 0.94$), after the dot probe task ($t(57) = -3.93$, $p = 0.001$, 95% CI -1.22 to -0.40, ES $d = 0.60$), and 5min after the task ($t(57) = -2.82$, $p < .001$, 95% CI -1.03 to -0.17, ES $d = 0.40$). In the exercise condition there were significant changes in feeling between baseline and post-treatment ($t(57) = -5.81$, $p < 0.001$, 95% CI -1.74 to -0.85, ES $d = 0.94$), after the dot probe task ($t(57) = -3.93$, $p = 0.001$, 95% CI -1.22 to -0.40, ES $d = 0.60$), and 5min after the task ($t(57) = -2.82$, $p < .001$, 95% CI -1.03 to -0.17, ES $d = 0.40$). In the exercise condition there were significant main effects of condition and time, and interactive effect of condition × time.

Note. Time 1 = baseline; 2 = mid-treatment; 3 = immediately post-treatment; 4 = after 2nd dot probe task; 5 = at 5min after the task

**Figure 4.11.** Mean (SEM) FAS over time by condition

Post hoc paired simple t-tests revealed that no baseline difference was shown between conditions, $t(57) = -1.74$, $p > 0.05$. There were significant differences between conditions at mid-treatment ($t(57) = -9.95$, $p < 0.001$, 95% CI -1.91 to -1.27, ES $d = 1.47$), post-treatment ($t(57) = -8.49$, $p < 0.001$, 95% CI -2.22 to -1.37, ES $d = 1.57$), and after the dot probe task ($t(57) = -4.48$, $p < 0.001$, 95% CI -1.22 to -0.47, ES $d = 0.72$). FAS in the exercise condition increased significantly between baseline and mid-treatment ($t(57) = -5.87$, $p < 0.001$), post-treatment ($t(57) = -5.55$, $p < 0.001$), and after the dot probe task ($t(57) = -2.84$, $p = 0.006$). The mean (SD) of the change scores of FAS were -0.58 (0.92) in the passive condition and 0.92 (1.27) in the exercise condition.
Given that BMI and PFS were correlated with some subjective measures at baseline (see Table 4.5), they were added to the above analyses as covariates to determine if it impacted on the reported main and interaction effects. Adding the covariates had no effect on the reported effects.

4.3.8. Does affect mediate the effects of exercise on attentional bias and cravings

The mediation analysis was conducted to test the relationships shown in Figure 4.3. However, the effects of condition on attentional bias or cravings were not mediated by FS or FAS.

4.3.9. Relationship between measures

Attentional bias and subjective measures

Table 4.10 shows the correlation between attentional bias following each condition and different subjective outcomes (using an average score for outcomes from measures at mid- and post-treatment scores).

There were no significant correlation between attentional bias measures and subjective measures in both conditions. Table 4.5 also showed no significant correlation between attentional bias and craving measures at baseline prior to exercise and passive conditions.

Subjective measures

The different subjective measures for chocolate cravings and hunger were significantly correlated with each other in the passive and the exercise condition (see Table 4.10). Table 4.5 also showed significant correlations among craving on VAS, desire to eat chocolate on FCCQ-S, and hunger at baseline.
Table 4.10. Correlation between attentional bias and subjective measures of cravings

<table>
<thead>
<tr>
<th>Subjective measures</th>
<th>Attentional Bias measures</th>
<th>Treatment</th>
<th>$r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chocolate craving (VAS)</td>
<td>Total AB</td>
<td>Passive</td>
<td>-0.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Initial AB</td>
<td>Passive</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>Maintained AB</td>
<td>Passive</td>
<td>-0.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise</td>
<td>0.16</td>
</tr>
<tr>
<td>Desire to eat chocolate (FCCQ-S)</td>
<td>Total AB</td>
<td>Passive</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Initial AB</td>
<td>Passive</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>Maintained AB</td>
<td>Passive</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise</td>
<td>0.12</td>
</tr>
<tr>
<td>Hunger (VAS)</td>
<td>Total AB</td>
<td>Passive</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>Initial AB</td>
<td>Passive</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Maintained AB</td>
<td>Passive</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise</td>
<td>0.15</td>
</tr>
<tr>
<td>Chocolate craving (VAS)</td>
<td>Desire to eat chocolate (FCCQ-S)</td>
<td>Passive</td>
<td>0.74***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise</td>
<td>0.77***</td>
</tr>
<tr>
<td>Hunger (VAS)</td>
<td>Passive</td>
<td>0.66***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exercise</td>
<td>0.83***</td>
<td></td>
</tr>
</tbody>
</table>

*** Correlation is significant at the 0.001 level (2tailed).

4.3.10. Summary of qualitative data

Interview data for 3 groups (normal weight- temporarily abstinent (TA), overweight -TA, and Lent) (see Appendix 8) is summarized in (see Table 4.11). The most frequent reasons for eating chocolate appeared to be when participants just had craving/thoughts about chocolate (29.13%) and mood-enhancing effect (26.21%). Eating chocolate appeared to be less triggered by feelings associated with activation, environmental cues (except for the overweight group), hunger, and being with others in a social gathering.
Table 4.11. Summary of interview data

<table>
<thead>
<tr>
<th>Variables</th>
<th>Normal weight-TA (N=20)</th>
<th>Overweight-TA (N=21)</th>
<th>Lent (N=17)</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAS (Deactivation)</td>
<td>1,2,3,4,6,8</td>
<td>7,8,11</td>
<td>5,15,16,17</td>
<td>13</td>
<td>12.62%</td>
</tr>
<tr>
<td>Low energy, fatigue, tired</td>
<td></td>
<td></td>
<td></td>
<td>(6+3+4)</td>
<td></td>
</tr>
<tr>
<td>FS (Pleasant, Lift mood, Boredom)</td>
<td>1,3,6,8,10,17</td>
<td>1,4,5,7,9,10,1</td>
<td>2,5,6,8,10,11,19</td>
<td>27</td>
<td>26.21%</td>
</tr>
<tr>
<td>Cues</td>
<td>5,9,11</td>
<td>3,5,6,10,18,19</td>
<td>4,10,13</td>
<td>14</td>
<td>13.59%</td>
</tr>
<tr>
<td>Hunger</td>
<td>3,4,12,14,15,18,20</td>
<td>4,7,8,10,12</td>
<td>5</td>
<td>12</td>
<td>11.65%</td>
</tr>
<tr>
<td>Craving/thoughts</td>
<td>7,9,11,12,13,14,15,19</td>
<td>2,4,9,10,11,14,19,20</td>
<td>1,3,4,7,9,13,14,17</td>
<td>30</td>
<td>29.13%</td>
</tr>
<tr>
<td>Social gathering</td>
<td>5,13</td>
<td>3,5,10</td>
<td>8,12</td>
<td>7</td>
<td>6.80%</td>
</tr>
</tbody>
</table>

Note. The subject numbers are presented in Appendix 8. Total number of subject = (normal weight-TA) + (overweight-TA) + (Lent).

4.4. Discussion

This is the first study to examine the effects of moderate intensity exercise on chocolate craving and attentional bias to chocolate-related cues among regular chocolate eaters. A 15 minute bout of moderate intensity exercise significantly reduced chocolate craving, hunger, and attentional bias to chocolate images, compared with changes associated with being passive. The current study extends previous evidence that exercise suppresses appetite (Bozinovski et al., 2009; Broom et al., 2009; Maraki et al., 2005; Blundell & King, 2000), reduces the urge to snack (Taylor & Oliver, 2009; Thayer et al., 1993), and attenuates ad libitum chocolate consumption (Study 1).
All subjective measures showed significantly lower values at the end of exercise and up to approximately 10mins after exercise (i.e., 5mins post-task) compared with the passive condition. Both chocolate measures appear to be mainly due to reductions from pre-post exercise, whereas effects on hunger were mainly due to increases from pre-post rest. Cohens $d$ values suggested moderate to large (0.54 - 0.80) effect size with little sign of any diminishing effects from immediately post to 10 mins post treatment. The reduced chocolate craving in this study is in line with previous findings. Urge to snack was significantly decreased immediately after a 5 min-walk (Thayer et al., 1993) and chocolate craving was reduced immediately and 10mins after a 15min-walk (Taylor & Oliver, 2009). Similar effect patterns have been shown in other substances (a review paper by Taylor, Ussher, & Faulkner, 2007). For example, Taylor and colleagues (2006) found that a self-paced 1-mile walking reduced desire to smoke during and up to 20mins after exercise. Ussher, Sampuran, Doshi, West, & Drummond (2004) reported a significant reduction in alcohol urges during 10mins moderate intensity exercise compared to baseline urge.

The effects of exercise on total attentional bias were largely a result of the effects on initial attentional bias. Exercise only reduced initial attentional bias but not maintained attentional bias and this was due to increases from pre-post in the control condition. However, a moderate effect size (Cohens $d$ values) between conditions was shown across all the attentional bias measures. It may suggest that the effects on maintained attentional bias were underpowered and with a larger sample size there would be a significant interaction effect. It is not easy to explain why the control condition led to an increase in attentional bias. It may be that the period without distraction of exercise gave participants time to think about the images they had seen in the 1st dot probe task. Elaborated Intrusion Theory (Kavanagh et al., 2005) suggested that subjective craving can be experienced as an ‘intrusion’, which is caused by external cues, and the elaborated imagery of the cues enhance the initial cravings. Future studies should include a distraction control condition to compare with a passive control and exercise intervention to test if exercise effects are due to distraction.

It is difficult to explain why the effects were shown only on initial attentional bias and not on maintained attentional bias. The two attentional bias measures measure different concepts: one is an automatic response and the other is the subsequent maintenance of attention. In previous attentional bias studies using the dot probe task, Kemps and Tiggerman (2009) found attentional bias toward chocolate images when presented for 500ms among chocolate cravers compared with non-cravers, but they did not consider a measure of maintained attentional bias. Brignell and colleagues (2009) used 500ms and 2000ms to present images of food and control to
examine the relationship between attentional bias and external eaters (H/L external eaters). They only found a significant main effect on external eating, and no interaction (external eating x stimuli duration). In other words, high-external eaters showed a significantly greater attentional bias for food cues than low-external eaters regardless of stimuli duration (500ms vs. 2000ms). Tapper, Pothos, and Lawrence (2010) examined the effects of hunger and trait reward drive on attentional bias to food related images by using 100ms, 500ms, and 2000ms stimulus duration. They only found the effects at 100ms, but not for longer duration. It may be possible that a 15-min moderate intensity exercise used in this study was not intensive or long enough to see an effect on maintained attentional bias.

Contrary to expectations, an effect of exercise on the delayed time from text messaging before eating chocolate was not shown when all groups were included in the analysis due to large standard deviations. However, when the data were clustered in 3 time frames, the percentage of people who ate immediately after the exercise session or within 1hr was smaller than those involved in the passive condition. Exercise tended to delay the time for consuming the next chocolate. This finding was extended from a previous study (Thayer et al., 1993). Thayer and colleagues (1993) also found that a 5min walk significantly extended the time until eating the next snack by almost 50% compared to not walking. However, in present study, it is not clear whether participants were in the same situation outside of the laboratory. For example, I could not be sure whether they ate something else (i.e., regular meal) before eating the chocolate and whether the time from the text was actually when they eat the chocolate bar as instructed. Also, it may be that possible some people ate chocolate immediately after completing test because they did not want to send a text. These could be the limitations of a naturalistic setting that researchers cannot control.

The role of affect in the relationship between exercise and outcome measures

In the present study, the large effect size indicated a significant increase in affect (FS & FAS) after exercise compared with the sedentary condition and in the passive condition affect remained stable. The effect of exercise on affect had been shown several previous studies (Ekkekakis et al., 2008; 2006; Taylor et al., 2006). A recent review paper (Ekkekakis et al, 2011) highlighted the positive effects of moderate intensity exercise on feelings of pleasure. Subject’s affect is closely associated with eating behaviour. For example, the relationship between mood (experimental mood manipulation) and attentional bias (visual dot probe task) was examined by Hepworth and colleagues (2010). They found that a negative mood group increased attentional bias for food cues and subjective appetite. In other words, the mood state influenced appetitive motivation. The increased attentional bias to chocolate images in the passive condition may be due to affective state. Although there were differences in the changes
in affect between the exercise and the passive condition, mediation analyses did not show any significant mediating effect of affect on chocolate craving or attentional bias and it is unclear why this was. It may be that the sample size was in sufficient to see any mediating effects.

**Participant characteristics**

The hypothesis was that overweight participants may have greater chocolate craving and attentional bias at baseline and the effect of exercise would be larger than for normal weight participants. However, no differences were found between groups with regard to attentional bias and subjective measures. Castellanos and colleagues (2009) used an eye tracker with a visual dot probe task with stimuli exposure duration of 2000ms to examine attentional bias for food-related images among normal weight and obese people. In reaction time scores from the visual dot probe task, they also did not find any differences between normal weight and an obese group. On the other hand, the data from the eye tracker showed that the group differences were shown in the fed condition and obese individuals spent more time on food images than non-food images, compared with normal weight. The Castellanos study suggests that obesity differences may be dependent on the measure used to assess attentional bias. Another explanation of this is the nature of participants. In the previous study mentioned above, participants were not heavy chocolate eaters and did not abstain from eating chocolate. They used more general food images such as high calorie food (e.g., ice cream, pizza), low calorie food (e.g., apple, broccoli), and non-food images (e.g., office supplies), rather than using specific food images (e.g., chocolate). In the present study, participants’ chocolate craving was generally high, in line with the study’s inclusion criteria.

It was also hypothesised that longer abstinence periods from eating chocolate would lead to greater chocolate cravings than temporarily abstinence. The group who had given up chocolate for Lent had a mean BMI similar to the normal weight group which was less than the overweight group. It was not therefore possible to compare low and high BMI in the Lent group. Interestingly, the Lent group had a similar mean Trait chocolate score (on the FCCQ-T) to the overweight, and both were higher than the normal weight group. The Emotional Eating score (on TFEQ-18) was higher in the overweight group than the normal weight group and the Lent group tended to have a higher score than the normal weight group. However, it is not easy to explain these findings.

In addition, in the aspect of the sample characteristics, participant in this study had higher levels of trait eating behaviour scores (e.g., hedonic hunger, restrained eating) compared with other studies. For instance, total mean PFS score (SD) in the study by Forman et al., (2007) was 36.42 (10.59) and the score in current study was 44.53 (11.23). TFEQ-18 scores were also higher
Measures of attentional bias and subjective craving

In this study, to measure visual attention, 200ms and 1000ms were used for initial attentional bias and maintained attentional bias. Field and Cox (2008) pointed out that multiple shifts in attention between the different stimuli are possible with a longer presentation of the stimuli than about 200ms. Further investigation is needed with various presentation duration, and using the visual dot probe task alongside other attentional bias measures (i.e., eye tracking). A few studies have used self-reported craving and attentional bias measures together (Hepworth et al., 2010; Janse Van Rensburg et al., 2009a). Hepworth and colleagues (2010) found a small correlation between attentional bias (dot probe task) and subjective appetite (on a 100mm-VAS) (r = 0.28, p < 0.05). Janse Van Rensburg and colleagues (2009a), with eye-tracking technology, only found a significant correlation between initial attentional bias and subjective desire to smoke in a control condition, but not in an exercise condition and no correlation with maintained attentional bias. The current study did not find a significant correlation between a self-reported measure of craving and measure of attentional bias at baseline.

Moderating effect of trait measures on the effects of exercise

It was hypothesised that higher scores on the trait measures (e.g., restrained eating, impulsivity) would be associated with greater cue induced chocolate craving. In previous studies, ‘restrained eaters’ were faster to detect a food word with speed detection task than ‘unrestrained eaters’ (Hollitt et al., 2010) and ‘high-external eaters’ showed a greater attentional bias for food cues (Brignell et al., 2009). Moreover, participants who have higher trait impulsivity revealed a greater change in desire to eat food after the food cue (Tetley et al., 2010). In contrast, the present study only found a significant correlation between PFS and subjective craving at baseline and did not find any significant relationship between trait measures and chocolate craving/attentional bias. One explanation is the small sample size compared with previous studies. The same size in this study may not have been sufficient to see any moderating effect of trait measures and on the effects of exercise on food cravings and attentional bias.
Strengths

The present study used two measures of subjective craving rather than just using a modified version of the State-food Craving Questionnaire (FCQ-S), which was used in the previous study (Study 1). The VAS-100mm has been widely used in appetite research and its validity and reliability have been shown in the previous research (Chaput et al., 2010; Mattes et al., 2005; Flint et al., 2000). The finding from this study suggests that the two measures (i.e., craving items from FCQ-S and the VAS-100mm) were highly correlated and exercise had the same effect on both measures. In addition, although the two subjective measures did not show a significant correlation with any attentional bias measure, exercise had an effect on subjective measures and total attentional bias.

In terms of participant characteristics, this study gives greater confidence in the generalizability of the findings than in a similar chocolate craving study, Taylor & Oliver (2009), which involved participants with a mean (SD) age of 25.3 (9.7). In the current study the mean age for whole sample was 29.64 (11.46) with range from 18 to 55. Moreover, participants recruited in this study were abstainers (for a lab study) and actual abstainers (in a naturalistic situation) rather than just temporarily abstained people which is commonly used in a laboratory based study.

Limitations

There are some limitations in this study. Firstly, participants were only female regular chocolate eaters so the findings may not generalise to males. However, evidence showed that a higher percentage of food cravers are females (Lafay et al., 2001) and females are more likely to prefer snack food than males (Wansink, Cheney, & Chan, 2003). Secondly, the repeated use of a small number of images in the attentional bias task may have lacked generalizability and salience for participants. However, most studies used a similar number of images (e.g., 20 food-related pictures for 160 trials; Hepworth et al., 2010 and 14 alcohol-related pictures for 112 critical trials; Field et al., 2005). I considered that the repeated (i.e., 4 times) use of the same images may have caused learning effects and less salience, thus 40 food-related pictures were used and there were fewer critical trials (i.e., 60). Lastly, only a short bout of moderated intensity exercise was used to examine the effects on craving and attentional bias. It is not known whether different intensities of exercise will have the same effects and further investigation is needed to explore dose response effects.


Practical implications

This is a unique study to examine the effect of moderate intensity exercise on chocolate cravings and attentional bias to chocolate images among regular chocolate consumers with different BMI and abstinence periods. The findings in this study imply that a 15min-brisk walk could help to regulate dysfunctional eating and it may be useful for everyone who experiences greater food-cue reactivity (attentional bias to food cues). We are exposed to food cues (e.g., visual images, smell of food) in daily life through the media or shops, and that makes it difficult to resist snacking for people who have a problem to self-regulate their eating. The present findings suggest that those susceptible to crave for chocolate may experience greater cravings and attentional bias if they remain inactive. Brisk walking is easy to access for everyone wherever they are, and the short bout of exercise helps to attenuate attentional bias and craving and its negative consequences. The effects are similar for both normal and overweight, and those who are abstaining over a period of time (during Lent).

Research implications

Further research is needed to examine the effects of exercise on cravings and attentional bias with direct measures of attentional bias (i.e., eye tracker), and determine whether higher intensity exercise has a greater effect. Differences post treatment in initial attentional bias appeared to be due to increases in the passive condition rather than decreases in the exercise condition. Further research is needed to explore if exercise can still have an effect on craving and attentional bias compared with other distracting task. It would also be useful to extend food cues from just chocolate images to various snack foods. All the participants in the present study were abstinent for at least 1day and it would be useful to conduct further studies to determine the effects of exercise in naturalistic settings similar to a study by Thayer (1987) but involving regular chocolate or other food snackers.

Conclusions

A short bout of exercise suppressed both attentional bias for chocolate cues and subjective cravings and hunger for normal, overweight and Lent abstainers. Exercise reduced subjective cravings but attentional bias and self-reported hunger increased after the passive condition. Therefore, the present findings may have importance for people who are struggled with dysfunctional eating to help them to successfully self-regulate snacking.
Chapter 5. Study 3

The effects of exercise on hedonic food and smoking cravings, and attentional bias among temporarily abstinent smokers

5.1. Introduction

Smoking is the biggest single cause of premature mortality (see for instance WHO, 2008). An important question is why many regular smokers cannot give up smoking in spite of its health benefits. Some people cannot give up smoking because of the so called “side effect” of smoking cessation such as withdrawal symptoms, negative affect, and cravings (see a review paper by Piasecki, 2006). Another reason is weight gain. Smokers experience almost 5 kg of weight gain per a year (Pisinger & Jorgensen, 2007b) and 9 kg over 8 years (Lycett et al., 2010) after smoking cessation. Perkins (1993) noted that many smokers are concerned about weight gain after cessation and normal weight women who were ex-smokers were significantly more likely to be frequently concerned than those who had never smoked.

Weight gain appears to be due to a slower metabolism and increase in total calories consumed, especially from sweet foods after smoking cessation. Increased energy intake may be to relieve stress, to satisfy oral desire, to substitute hand activity, and to overcome disruption in insulin level (Logue, 1996). Spring and colleagues (2003) also suggested that abstinent smokers may increase the reward value of snack foods. Smokers may experience both increased food cravings and cigarette cravings when nicotine inhibited because nicotine has the function of suppressing hunger. The ‘Incentive-Sensitization Theory’ (Robinson & Berridge, 2001) further supports that the nicotine deprivation condition could produce a reward deficiency state, which increases motivational salience to accessible rewards. There are studies showed that glucose tablets can help to control cravings for cigarettes and help with quitting in short term (West, Courts, Beharry, May, & Hajecck, 1999; West & Wills, 1998), although its long-term effects on smoking cessation are not clear (see a review by West, May, McEwen, McRobbie, Hajek, & Bangeli, 2001). However, those findings add further explanations why smokers find an alternative reward (e.g., snacking) to avoid withdrawal symptoms.

Previous studies have examined the relationship between smoking cessation and weight gain among participants abstaining from smoking in the short (Perkins, Sexton, DiMarco, & Fonte, 1994; Hatsukami et al., 1993) or long-term (Lycett et al., 2010), or by comparing smokers and non-smokers (Spring et al., 2003; DiLorenzo and colleagues, 1991). For example, DiLorenzo
and colleagues (1991) compared the changes in craving for high-caloric food (cookies) among three groups (i.e., smokers, non-smokers and quitters), and found that only quitters showed an increased weight gain (approximately 5 lbs) from baseline to a 5-week follow-up and greater snack food consumption during *ad libitum* eating. A cross-sectional study (Facchini et al., 2005) involved 144 smokers and non-smokers. Smokers who were also high on a Restraint Eating scale indicated significantly higher scores on items about hunger, eating, and weight, and showed a greater level of support for the belief that ‘smoking helps to control weight’ compared to non-smokers who were also low on the Restraint Eating scale. This survey indicated that regular smokers find it difficult to quit smoking because of concern for weight gain, and smoking cessation could lead to substituting unhealthy behaviour such as snacking. Despite awareness of this, most studies have focused on confirming the general relationship between smoking cessation and weight gain, with only a few studies looking at the craving for specific food on cessation from smoking and how to overcome this problem.

Physical activity has been promoted as a smoking cessation aid (Ussher, Taylor & Faulkner, 2008). Also, a number of studies support the role of physical activity as an intervention to regulate certain addictive behaviours during temporary abstinence such as alcohol (Ussher et al., 2004) and smoking (Janse Van Rensburg et al., 2009a, 2009b; Taylor, Ussher & Faulkner, 2007). There is some evidence that exercise could temporarily reduce strength of cravings and desire to smoke (Taylor, Ussher & Faulkner, 2007), and desire to eat certain sweet food (Taylor & Oliver, 2009). Also, a recent Cochrane Review (Parsons, Shraim, Inglis, Aveyard, & Hajek, 2009) reports that exercise interventions had a significant effect on reducing weight gain during smoking cessation for the first 12 months. However, no previous study has examined whether exercise reduces not only an individual’s desire to smoke, but also the desire to snack during smoking abstinence. Whether the intensity of exercise has a different effect on subjective desire to snack has also not been investigated.

There are several ways of measuring interest in certain substances such as self-reported urge and *ad libitum* behaviour. Self-report is the most commonly used measure because of its ease of use, but responses may be biased. Although there is some evidence that cravings vary between abstinence and satiety, and they increase in response to salient cues, other measures can also be useful in understanding how an individual is attracted to cues that may trigger a relapse during abstinence. The tendency to selectively attend to personally relevant information over neutral information is called ‘attentional bias’ (Mathews & MacLeod, 2005). This is consistent with Robinson and Berridge’s (1993) incentive salience account of craving and addiction.
Attentional bias has been measured by indirect measures such as the adapted Stroop task (Domier, Monterosso, Brody, Simon, Mendrek, & Olmstead et al., 2007) and the dot probe task (Field, Mogg, & Bradley, 2005), and direct measures such as an eye tracking system (Miller & Fillmore, 2010; Janse Van Rensburg et al., 2009a). Janse van Rensburg and colleagues (2009a) examined the effects of exercise on attentional bias toward smoking-related still images, using an eye tracker to capture the percentage of initial fixations and duration of time spent looking at salient versus neutral cues. They found that a 15 min period of moderate intensity exercise reduced attentional bias to smoking cues during temporary abstinence (compared with a rest condition). One study, Taylor, Oliver, and Janse Van Rensburg (2009) assessed the acute effects of brisk walking on attentional bias to chocolate still images, using an eye tracker, among regular chocolate eaters. They found that after a period of abstinence from eating chocolate, the moderate intensity exercise significantly reduced attentional bias to chocolate images. Unlike other addiction studies, the use of an eye tracker to assess attentional bias toward food is rare and no study has involved video clips. Use of video may be more vivid and closer to a naturalistic environment/cue, rather than still images.

The previous study (Study 2) looked at the acute effects of exercise on attentional bias using a visual dot probe task and found that a single bout of exercise reduces chocolate cravings and attentional bias to chocolate-related stimuli. There is a need to determine if these findings are consistent with other direct measures of attentional bias (e.g., using eye tracking technology). This study also builds on the Study 1, which may not have been powerful enough to elicit sufficiently strong cravings, or detect large effects from only moderate intensity exercise. In the following study, abstinence from smoking and snack food may create a more powerful scenario for eliciting interest in the food cues.

Thus, the purpose of this study was to assess whether a 15-minute bout of moderate or vigorous exercise, compared with a passive rest condition, reduces attentional bias to snack food and cigarette video clips, compared with neutral images, among temporarily abstinent smokers. Also, the aim was to examine the relationship between attentional bias and self-reported food and smoking cravings.

5.2. Methodology

5.2.1. Participants

Eighty-three participants responded to public poster advertisements and by sending e-mails to student groups. Of the 83 participants, 58 people were excluded after screening and Eye-
tracking technology problems (eye colour) and 2 participants did not complete all sessions. Firstly, participants were screened using a Physical Activity Readiness Questionnaire and Cardiovascular disease (CVD) risk factor assessment for exercise testing and prescription (see Appendix 9). Then, they were involved in calibration to check whether the eye-tracking camera could follow their eye movement. If they wore glasses, they were excluded because the light reflecting from it interfered with the camera sensor. Thus, a total of 23 participants were recruited who satisfied the inclusion criteria (i.e., were aged 18-45 years, smoked at least 10 cigarettes a day, had been a regular smoker for 2 years or more, and at one chocolate bar per day and consumed other snacks on a regular basis). Participants were required to be free from injury/illness that could inhibit their ability to safely exercise at a moderate or vigorous intensity.

5.2.2. Procedure

Prior to arrival participants were asked not to eat, drink (except water) or exercise for 2 hours and abstain from smoking for 15 hours before the testing session. This period of abstinence has been shown to increase cigarette cravings and withdrawal symptoms (Ussher et al., 2001). Participants were requested not wear eye-make up or oil based facial products that may have interfered with the ability of the technology to detect eye movements. People who meet the inclusion criteria were randomly assigned to engage in 3 treatment conditions in different orders (on separate days): (1) Low-moderate intensity exercise; (2) Vigorous intensity exercise; (3) Passive control, in a within-subjects cross-over design. The three sessions were attended within the same week and at approximately the same time of day (between 7am and 12pm).

The participants were fitted with a heart rate monitor worn throughout the session to measure exercise intensity and cardiovascular reactivity to cues, with data being recorded over 15sec epochs. At the beginning of each session, expired Carbon Monoxide (CO) levels were recorded using a Bedfont Smokerlyzer (Bedfont Scientific Ltd, Kent, England) to confirm cigarette abstinence with absolute levels of CO < 10 parts per million (ppm). They were then shown packets of high energy snack food (e.g., chocolate, biscuits, crisps) for 10 sec but not allowed to eat them to elicit food cravings.

*Exercise treatment:* The exercise session consisted of a 2 minute warm-up, followed by a 15 minute semi-self-paced low-moderate intensity cycling at 40-50% HRR and RPE = 11 - 13 (i.e., fairly light-somewhat hard) or 15 minute vigorous intensity cycling at 70-75% HRR and RPE = 15 - 17 (i.e., hard-very hard) on a cycle ergometer, and a 2 min cool down. Participants were instructed to keep intensity within 11 - 13 on RPE Scale for low-moderate intensity and 15 - 17
on RPE Scale for vigorous intensity exercise, as defined by the American College of Sports Medicine (ACSM, 2006). The participants were told, “I would like you to select a speed and resistance to keep the same level of RPE while exercising”, and load/resistance was adjusted depending on their response. HR, RPE, RPM, Watts, and load/resistance were measured each 3 minutes.

**Passive treatment**: Participants were required to sit passively and quietly at a desk for 17 minutes (to keep the same period of time used in the exercise conditions).

At baseline and 5 minutes post-treatment in each session, attentional bias (% of fixation and dwell time) was measured by an eye-tracking system. The participants were seated at a desk approximately 95cm in front of a computer screen and eye tracking camera (Pan/Tilt optics system, Model 504, Applied Science Laboratories (ASL), Bedford, England). The camera (60 Hz output) was placed 69cm from the participant and it linked to the eye tracking system (Model 5000 control unit, Eyeline II Eye-tracking System, Applied Science Laboratories), which processed the eye image. Participants were asked to look at 16 randomly presented matched pairs of videos (8 pairs of snacking/neutral and 8 pairs of smoking/neutral video images) (see Picture 1).

**Picture 1.** A computer screen and eye tracking camera

Subjective measures of food and cigarette urges, Mood and Physical Symptoms Scale (MPSS, West and Hajek, 2004), and affect were assessed at (1) baseline, (2) mid-point of treatment, (3) immediately post-treatment, and (4) post-video observation and during the exercise session participants responded verbally.

To avoid participant reactivity to assessments, at the end of the final sessions, participants completed the Revised Restraint Scale (RS, Polivy, Herman, & Warsh, 1978) to measure restrained eating, Three-Factor Eating Questionnaire-R18 (TFEQ-R18, de Lauzon et al., 2004) to determine their two different aspects of eating behaviour (uncontrolled eating and emotional eating), Power of Food Scale (Lowe et al., 2009) to measure trait hedonic hunger, the Barratt
Impulsiveness Scale (Spinella, 2007), the validated Fagerstrom Test for Nicotine Dependence (FTND, Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991b) to measure self-reported levels of nicotine dependence, and the short form of the International Physical Activity Questionnaire (IPAQ, Craig, Marshall, Sjostrom, Bauman, Booth, & Ainsworth, et al., 2003) to assess recent levels of physical activity.

At the end of the final testing session, participants received a £20 payment for their participation. Figure 5.1 shows the time frame for measure.

Figure 5.1. The time frame for measures

5.2.3. Measures

Attentional bias

To measure attentional bias a close-up telephoto image of each participant's eye was obtained by an auto-focusing lens system. Vertical and horizontal displacement between the centre of the pupil and the corneal reflection were measured by the eye tracking system.

Three separate monitors were used within the procedures (see Picture 2). The first screen (20 × 16cm) (see left on pic a) displayed the duplicate participants’ screen and the participants’ gaze point on the screen marked by a white cross. This screen was used to check the procedure of videos and capturing eye movement. The second screen (26 × 21cm) (see right on pic a) showed a detailed image of the participants’ eye with a white cross, which appeared when the camera recognised the eye movement (pupil and cornea). The third computer screen (34 × 27.5cm) was
used to adjust the eye-camera setting by using the Eye-Trac 6000 user Interface program (see pic b).

**Picture 2.** Three screens used for eye tracking system: the first screen (left on pic a), the second screen (right on pic a), and the third screen (pic b)

A 9-point calibration screen (9 small circles in a $3 \times 3$ array) was displayed on the participants’ computer monitor for a calibration procedure to check the direction of the camera, the zoom, and the illuminator (see Appendix 10). During calibration, the cornea/pupil discrimination and pant/tilt tracking were set to auto, and the position of participants’ gaze on the screen was recorded. After the adjustment, video clips were presented on the participants’ computer screen (see Picture 1) and at the same time the output data were recorded. The data for each video clips were classified by time markers numbering 0 - 7 from the recording programme.

Video clips were filmed using digital technology (Sony Digital Camera, Dsc-T77, Tokyo, Japan). Videos clips were taken of snack foods that were considered to hold hedonic properties. For example, clips included holding food items (milk chocolate Hobnobs; Walkers crisps, Bourbon cream biscuits; Haribo sweets; white and milk chocolate cake; Cadbury’s milk chocolate; Jaffa cakes; and Guylian Belgian chocolate seashells). The neutral video clips to contrast with snacking video clips were taken of common household or outdoor objects (paperclips, shells, tea bag, washing-up bowl, leaves, garden folk, and tree branch). The smoking video clips consisted of an individual blowing smoke, lighting a cigarette and offering a cigarette from a pack. These smoking video clips were compared to matched neutral video clips including blowing the seeds off a dandelion, lighting a candle, and offering a pen from a pack. Video clips were taken with the intention of matching them with other clips and presenting them together. Each pair of video clips (snacking and neutral/smoking and neutral) was matched as well as possible for movement, contrast, darkness, size, shape and colour. The examples of snacking/smoking video clips are shown in Appendix 10.
Each separate video clip was imported into a film editing software (Microsoft Windows movie maker, Version 5.1) and was trimmed to 7000ms, with the first 1000ms frame of the video clip being used for a still image. Previous research has used still images rather than video to measure attentional bias, so the aim was to assess visual attention to this before the longer video clip. The still image and moving clip was transferred to a video production timeline. The still image was adjusted to 1200ms which has been used in other attentional bias research (Janse Van Rensburg et al., 2009a). The 7000ms video clip was added to this timeline after the still image. Thus, each sequence to be viewed was 8200ms in total. Finally, at the start of the timeline a cross on the screen was displayed for 2000ms.

The presentation of the paired video was formed using Microsoft Office PowerPoint 2003 with the following constraints: 1) the video compilations were resized to 9.5cm height and 11cm width, with 3.4cm of the distance between the inner edges of each video (1° visual angle); 2) both videos were adjusted to play simultaneously, and the order of images and side of the screen were randomly presented using a computer program (www.random.org/sequences); 3) the total 16 pairs of video clips (snacking and smoking video clips, including cross screen 10,200ms each) lasted approximately 81,600ms. A total of six randomised 8 pairs of snacking/neutral video clips and 8 pairs of smoking/neutral video clips were produced and smoking/neutral video clips played following snacking/neutral video clips. As smoking cues are a strong stimulus for smokers compare to food cues, the snacking video clips were presented first. Participants did not watch the same sequence of videos during different sessions.

Participants were instructed that: “you are required to watch a series of short videos of food and smoking, and while watching this camera will record your eye image. For accuracy, please keep your head as still as possible while watching the video clips. Before watching video clips, I am going to do a quick calibration. Please focus on point 5. Could you look at point 1… and point 9 please… thank you. Again, please try to keep as still as possible and focus on the centre of the cross each time it appears. It is very important to look at the centre of the cross before watching each food/smoking video clip. Now, the food video clips will begin….Now, you will see smoking video clips. Thank you.”

**Self-reported measures**

**Desire to snack.** Desire to snack was assessed using the following items (modified from FCCQ-S, Cepeda-Benito et al., 2000b): “I have an intense desire to eat a snack”, “I am craving a snack”, “I have an urge for snacking” on a 5-point scale (1 = strongly disagree, 5 = strongly
agree). The individual scores of these three items added up to provide the total score of desire to snack, with the total score ranging from 3 to 15.

**Strength of desire to smoke.** Strength of desire to smoke was assessed using an item: “How strong are your smoking urges now?” (West & Hajek, 2004) on an adapted 6-point scale (0 = no urges, 5 = extremely strong).

**Withdrawal symptoms.** Five items from the Mood and Physical Symptoms Survey (MPSS, West and Hajek, 2004), (i.e., depression, irritability, restlessness, hunger and poor concentration) were used to measure withdrawal symptoms. Participants rated the extent to which they felt commonly-reported withdrawal symptoms ‘at this moment in time’ on an adapted 5-point scale, ranging from 1 (not at all) to 5 (extremely) which has previously been used by Taylor & Katomeri (2007). For analysis purposes, all responses to the items were combined together to form a composite score for cigarette withdrawal symptoms.

**Affect.** The 11-point Feeling Scale (from -5 to +5; low to high feeling of pleasure) (Hardy & Rejeski, 1989) and the 6-point Felt Arousal Scale (from 1 to 6; low to high feeling of activation/arousal) (Svebak & Murgatroyd, 1985) were used to assess affective valence and activation throughout the study. Questionnaires used in this study are shown in Appendix 11.

### 5.2.4. Data analysis

**Analysis of attentional bias data**

The eye tracking data were analysed using The Eye-Trac 6000 Data Analysis Program (Eyenal, version V2 32, Applied Science Group 2001-2004). This software extracted the direction of the participant’s gaze with data sampling set at every 17ms. A fixation was defined when the subject’s eyes were stabilised on a particular position (within a 1° visual angle) for 100ms or more as recommended (Mogg et al., 2003). As recommended in the previous study (Bradley et al., 2007; Mogg et al., 2005) fixations on either the snacking/smoking or neutral image were defined if visual gaze was at least a ± 1° wide of the central position on horizontal plane (away from the centre of the cross that was shown prior to each video sequence). Thus, fixations were excluded if data points fell within this horizontal angle of the central cross and if the duration of fixation was for 99ms or less (Field et al., 2004; Janse van Rensburg et al., 2009a; Mogg et al., 2003). The measures of attentional bias were derived from the recorded data: the direction of initial fixation and the percentage of dwell time.
'The direction (and %) of initial fixation' was defined as the first eye movement within the area of interest on either the snacking/smoking or neutral images at least 100ms after the image onset (Bradley et al., 2007; Mogg et al., 2005). A direction bias score was calculated for each participant by calculating the number of trials when the initial shift in gaze was directed initially towards the snacking/smoking-related images as a percentage of overall critical trials. Scores greater than 50% reflect a bias towards initial orientation of snacking/smoking images compared with neutral images (Mogg et al., 2005).

'Percentage dwell time’ was defined as the overall percentage of time fixated on either snacking/smoking or neutral image over the video presentation. Thus, the percentage dwell time on snacking/smoking video clips was calculated by dividing the total fixation time on snacking/smoking video clips by total fixation time (all fixation: snacking/smoking + neutral video clips) as recommended (Janse Van Rensburg et al., 2009a; Mogg et al., 2003).

Statistical analysis

SPSS (version 16) was used to analyse the data. Descriptive analyses were used to describe the participant’s demographic data. Baseline values for attentional measures and self-reported measures were compared using a one-way ANOVA to identify possible differences prior to each condition and any effects of order. ANOVAs, with post hoc t-test were used to check for expected differences in HR and RPE between conditions. For analysing attentional bias data (% initial fixations and dwell time), repeated measures ANOVAs were conducted from pre- to post-treatment across each condition to examine any differences between snacking/smoking videos and control videos. Fully repeated measures ANOVAs, 3 (condition: passive, moderate exercise, and vigorous exercise) × 4 (time: baseline, mid-treatment, post-treatment, and after watching video clips), were performed to determine any differences in self-reported measures of food and smoking cravings, total withdrawal symptoms (MPSS), hunger (a single item from MPSS), and affect. All significant interactions and main effects were assessed using p < 0.05 and Bonferroni correction was applied when t-tests were administered. To determine relationships between the changes in affect after exercise and attentional bias and between subjective measures (from self-reported craving) and objective measures (attentional bias data) of snacking/smoking cravings correlations were investigated.
5.3. Results

5.3.1. Participant demographics and baseline information

Demographic data for twenty three participants (15 males and 8 females) are shown in Table 5.1 and Table 5.2. There were no significant differences between each of the three conditions (passive control, moderate exercise, and vigorous exercise condition) at baseline for heart rate (HR), Feeling Scale (FS), Felt Arousal Scale (FAS), the Mood and Physical Symptoms Scale (MPSS) score, desire to snack, strength of desire to smoke, and attentional bias for snacking and smoking, p > 0.05.

Table 5.1. Participant demographic and background variable data

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean (SD) score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.96 (4.83)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.47 (2.98)</td>
</tr>
<tr>
<td>Nicotine dependence (FTND)</td>
<td>2.78 (1.78)</td>
</tr>
<tr>
<td>Trait hedonic hunger (PFS)</td>
<td>42.48 (11.93)</td>
</tr>
<tr>
<td>Dietary restraint (RS)</td>
<td>11.04 (5.96)</td>
</tr>
<tr>
<td>TFEQ</td>
<td></td>
</tr>
<tr>
<td>Uncontrolled eating</td>
<td>22.26 (5.07)</td>
</tr>
<tr>
<td>Emotional eating</td>
<td>6.70 (1.94)</td>
</tr>
<tr>
<td>Impulsivity (BIS)</td>
<td>36.00 (7.70)</td>
</tr>
<tr>
<td>Weight gain experience (kg/month)</td>
<td>2.05 (1.70)</td>
</tr>
<tr>
<td>Physical activity (day/week)</td>
<td></td>
</tr>
<tr>
<td>Walking:</td>
<td>5.48 (1.88)</td>
</tr>
<tr>
<td>Moderate:</td>
<td>1.74 (1.36)</td>
</tr>
<tr>
<td>Vigorous:</td>
<td>1.30 (1.46)</td>
</tr>
</tbody>
</table>

Note. FTND = Fagerstrom Test for Nicotine Dependence; PFS = Power of Food Scale; RS = Restraint Scale; TFEQ = Three-Factor Eating Questionnaire-R18; BIS = the Barratt Impulsiveness Scale
Table 5.2. Baseline mean (SD) for outcome variables by treatment

<table>
<thead>
<tr>
<th></th>
<th>Baseline mean (SD)</th>
<th>Treatment</th>
<th>F(df)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passive control</td>
<td>Moderate exercise</td>
<td>Vigorous exercise</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>73.67 (9.12)</td>
<td>70.98 (8.77)</td>
<td>69.97 (9.78)</td>
</tr>
<tr>
<td>FS</td>
<td>1.70 (1.52)</td>
<td>1.70 (1.64)</td>
<td>1.65 (1.67)</td>
</tr>
<tr>
<td>FAS</td>
<td>3.26 (1.25)</td>
<td>3.09 (1.20)</td>
<td>3.35 (1.11)</td>
</tr>
<tr>
<td>MPSS</td>
<td>10.48 (3.33)</td>
<td>11.26 (3.51)</td>
<td>10.78 (2.78)</td>
</tr>
<tr>
<td>Desire to snack</td>
<td>9.78 (3.72)</td>
<td>10.65 (3.21)</td>
<td>10.70 (2.57)</td>
</tr>
<tr>
<td>Hunger (from MPSS)</td>
<td>2.87 (1.22)</td>
<td>3.04 (1.11)</td>
<td>2.83 (0.94)</td>
</tr>
<tr>
<td>Strength of desire to smoke</td>
<td>2.48 (1.28)</td>
<td>2.61 (1.12)</td>
<td>2.35 (1.27)</td>
</tr>
<tr>
<td>H-AB snacking</td>
<td>70.07 (24.49)</td>
<td>72.60 (22.42)</td>
<td>67.71 (25.00)</td>
</tr>
<tr>
<td>M-AB snacking</td>
<td>62.00 (17.60)</td>
<td>64.90 (14.15)</td>
<td>64.84 (15.66)</td>
</tr>
<tr>
<td>H-AB smoking</td>
<td>70.70 (17.96)</td>
<td>64.31 (23.35)</td>
<td>63.25 (17.06)</td>
</tr>
<tr>
<td>M-AB smoking</td>
<td>65.45 (17.06)</td>
<td>62.40 (16.66)</td>
<td>65.35 (13.23)</td>
</tr>
</tbody>
</table>

Note. FS = Feeling Scale; FAS = Felt Arousal Scale; MPSS = Mood and Physical Symptoms Scale; I-AB snacking = initial fixation (% first fixations) on snacking; M-AB snacking = dwell time (% dwell time) on snacking; I-AB smoking = initial fixation on smoking; M-AB smoking = dwell time on smoking

5.3.2. Manipulation checks

The mean heart rate (HR), heart rate reserve (HRR), and rating of perceived exertion (RPE) scores for three conditions are shown in Table 5.3. The results fell within the range of intensities of moderate and vigorous exercise suggested by the American College of Sports Medicine (2009). Paired-Samples t-tests confirmed that there were significant differences in HR between conditions (control-moderate: t(22) = -22.10, p < 0.001; control-vigorous: t(22) = -31.74, p < 0.001; moderate-vigorous: t(22) = -12.73, p < 0.001).
Table 5.3. Means (SD) for HR, HRR, and RPE

<table>
<thead>
<tr>
<th>Variables</th>
<th>Passive control</th>
<th>Moderate exercise</th>
<th>Vigorous exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (bpm)</td>
<td>69.48 (9.04)</td>
<td>128.73 (13.65)</td>
<td>165.07 (14.49)</td>
</tr>
<tr>
<td>HRR (%)</td>
<td>n/a</td>
<td>45.82 (10.28)</td>
<td>75.46 (9.38)</td>
</tr>
<tr>
<td>RPE</td>
<td>n/a</td>
<td>12.79 (0.45)</td>
<td>16.70 (0.69)</td>
</tr>
<tr>
<td>RPM</td>
<td>n/a</td>
<td>77.08 (13.38)</td>
<td>77.26 (14.71)</td>
</tr>
<tr>
<td>Watt</td>
<td>n/a</td>
<td>89.05 (19.60)</td>
<td>138.59 (31.02)</td>
</tr>
</tbody>
</table>

5.3.3. Correlations between cravings and attentional bias measures

To examine the correlation between different measures of cravings and attentional bias measures, correlation analyses were carried out between subjective cravings for snack food and cigarettes and attentional bias at baseline following each condition. Table 5.4 shows that there were moderately strong correlations between both craving measures and maintained attentional bias (% of dwell time) at baseline, with the exception of prior to the moderate exercise condition. Craving measures were not correlated with initial attentional bias measures across conditions, but attentional bias to cigarettes in the moderate exercise condition was correlated.

Table 5.4. Correlations between subjective measures and attentional bias measures at baseline

<table>
<thead>
<tr>
<th>Subjective measures</th>
<th>Attentional bias measures</th>
<th>Treatment</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desire to snack</td>
<td>% of initial fixation</td>
<td>Passive</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>% of dwell time</td>
<td></td>
<td>0.69**</td>
</tr>
<tr>
<td></td>
<td>% of initial fixation</td>
<td>Moderate</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>% of dwell time</td>
<td></td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>% of initial fixation</td>
<td>Vigorous</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>% of dwell time</td>
<td></td>
<td>0.45*</td>
</tr>
<tr>
<td>Strength of desire to smoke</td>
<td>% of initial fixation</td>
<td>Passive</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>% of dwell time</td>
<td></td>
<td>0.53**</td>
</tr>
<tr>
<td></td>
<td>% of initial fixation</td>
<td>Moderate</td>
<td>0.49*</td>
</tr>
<tr>
<td></td>
<td>% of dwell time</td>
<td></td>
<td>0.66**</td>
</tr>
<tr>
<td></td>
<td>% of initial fixation</td>
<td>Vigorous</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>% of dwell time</td>
<td></td>
<td>0.46*</td>
</tr>
</tbody>
</table>

* p < 0.05; ** p < 0.01
5.3.4. Effects of condition order on outcome values

A 3-way mixed ANOVA, 6 (order) × 3 (condition) × 4 (time: baseline, mid-treatment, post-treatment, after watching video clips) for subjective measures, and with time = 2 (i.e., pre and post-treatment) for attentional bias, revealed that session order did not interact with condition and time, with any outcome variables (p > 0.05)(see Table 5.5).

Table 5.5. Testing the effects of condition order on condition × time interactions for the main outcome variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Order x condition x Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desire to snack</td>
<td>F(30, 102) = 1.16</td>
</tr>
<tr>
<td>Hunger (from MPSS)</td>
<td>F(30, 102) = 1.44</td>
</tr>
<tr>
<td>Strength of desire to smoke</td>
<td>F(16.84, 57.27) = 1.02</td>
</tr>
<tr>
<td>I-AB snacking</td>
<td>F(10, 34) = 0.34</td>
</tr>
<tr>
<td>M-AB snacking</td>
<td>F(10, 34) = 0.47</td>
</tr>
<tr>
<td>I-AB smoking</td>
<td>F(10, 34) = 1.31</td>
</tr>
<tr>
<td>M-AB smoking</td>
<td>F(10, 34) = 1.22</td>
</tr>
<tr>
<td>FS</td>
<td>F(30, 102) = 0.57</td>
</tr>
<tr>
<td>FAS</td>
<td>F(30, 102) = 0.66</td>
</tr>
<tr>
<td>MPSS</td>
<td>F(30, 102) = 0.83</td>
</tr>
</tbody>
</table>

Note. I-AB snacking = initial fixation on snacking; M-AB snacking = dwell time on snacking; I-AB smoking = initial fixation on smoking; M-AB smoking = dwell time on smoking

5.3.5. Effects of exercise on self-reported snacking and smoking craving

Fully repeated measures ANOVAs, 3 (condition: passive, moderate, and vigorous exercise) × 4 (time: baseline, mid-treatment, post-treatment, and after watching video clips), revealed significant main effects of condition and time, and interactive effect of condition × time on self-reported snacking and smoking craving, affect, and withdrawal symptoms (see Table 5.6).

Desire to snack

There were significant main effects of condition and time and interactive effect of condition × time, as shown in Figure 5.2 and Table 5.6.
Table 5.6. Mean (SD), and main and interactive effects of condition and time for subjective measures

<table>
<thead>
<tr>
<th>Variable (Time)</th>
<th>Condition</th>
<th>Effect (main, interaction)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passive control</td>
<td>Moderate exercise</td>
<td>Vigorous exercise</td>
</tr>
<tr>
<td><strong>Desire to snack</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>9.78 (3.72)</td>
<td>10.65 (3.21)</td>
<td>10.70 (2.57)</td>
</tr>
<tr>
<td>Mid-treatment</td>
<td>9.91 (3.84)</td>
<td>7.96 (3.48)</td>
<td>5.83 (3.19)</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>10.39 (3.76)</td>
<td>8.83 (3.73)</td>
<td>6.35 (3.39)</td>
</tr>
<tr>
<td>After video clip</td>
<td>10.65 (3.43)</td>
<td>10.00 (3.59)</td>
<td>8.09 (3.29)</td>
</tr>
<tr>
<td><strong>Subjective hunger</strong></td>
<td>(from MPSS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>2.87 (1.22)</td>
<td>3.04 (1.11)</td>
<td>2.87 (0.87)</td>
</tr>
<tr>
<td>Mid-treatment</td>
<td>2.96 (1.26)</td>
<td>2.48 (1.20)</td>
<td>1.96 (1.11)</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>3.04 (1.19)</td>
<td>2.22 (1.20)</td>
<td>1.70 (0.82)</td>
</tr>
<tr>
<td>After video clip</td>
<td>3.00 (1.24)</td>
<td>2.65 (1.15)</td>
<td>2.09 (0.85)</td>
</tr>
<tr>
<td><strong>Strength of desire to smoke</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>2.48 (1.28)</td>
<td>2.61 (1.12)</td>
<td>2.35 (1.27)</td>
</tr>
<tr>
<td>Mid-treatment</td>
<td>2.65 (1.23)</td>
<td>0.96 (0.98)</td>
<td>0.65 (1.34)</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>2.57 (1.38)</td>
<td>0.87 (1.06)</td>
<td>0.61 (0.99)</td>
</tr>
<tr>
<td>After video clip</td>
<td>2.91 (1.44)</td>
<td>2.0 (1.17)</td>
<td>1.17 (1.15)</td>
</tr>
<tr>
<td></td>
<td>FS</td>
<td>FAS</td>
<td>MPSS</td>
</tr>
<tr>
<td>----------</td>
<td>---------------------</td>
<td>--------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>Mid-treatment</td>
<td>Post-treatment</td>
</tr>
<tr>
<td></td>
<td>1.70 (1.52)</td>
<td>1.30 (1.64)</td>
<td>10.48 (3.33)</td>
</tr>
<tr>
<td></td>
<td>1.70 (1.64)</td>
<td>2.00 (1.28)</td>
<td>11.26 (3.51)</td>
</tr>
<tr>
<td></td>
<td>1.65 (1.67)</td>
<td>0.13 (1.77)</td>
<td>10.78 (2.78)</td>
</tr>
<tr>
<td></td>
<td>(1) condition</td>
<td>(2) time</td>
<td>(1) condition</td>
</tr>
<tr>
<td></td>
<td>$F(2, 44) = 5.38^{**}$</td>
<td>$F(2.10, 46.23) = 5.16^{**}$</td>
<td>$F(2, 44) = 11.64^{***}$</td>
</tr>
<tr>
<td></td>
<td>Mid-treatment</td>
<td>2.43 (1.70)</td>
<td>8.26 (2.78)</td>
</tr>
<tr>
<td></td>
<td>2.00 (2.00)</td>
<td>2.00 (2.00)</td>
<td>8.65 (2.23)</td>
</tr>
<tr>
<td></td>
<td>(3) interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$F(6, 132) = 7.73^{***}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-treatment</td>
<td>1.26 (1.89)</td>
<td>11.48 (3.74)</td>
</tr>
<tr>
<td></td>
<td>2.6 (1.63)</td>
<td>8.3 (2.64)</td>
<td>8.3 (2.64)</td>
</tr>
<tr>
<td></td>
<td>1.61 (1.85)</td>
<td>7.70 (2.06)</td>
<td>7.70 (2.06)</td>
</tr>
<tr>
<td></td>
<td>(3) interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$F(6, 132) = 10.89^{***}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>After video clip</td>
<td>2.83 (1.40)</td>
<td>11.26 (3.72)</td>
</tr>
<tr>
<td></td>
<td>2.6 (1.04)</td>
<td>9.78 (3.29)</td>
<td>9.78 (3.29)</td>
</tr>
<tr>
<td></td>
<td>3.43 (1.12)</td>
<td>8.61 (1.78)</td>
<td>8.61 (1.78)</td>
</tr>
<tr>
<td></td>
<td>(3) interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$F(4.54, 99.95) = 12.93^{***}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>3.26 (1.25)</td>
<td>10.48 (3.33)</td>
</tr>
<tr>
<td></td>
<td>3.09 (1.20)</td>
<td>11.26 (3.51)</td>
<td>11.26 (3.00)</td>
</tr>
<tr>
<td></td>
<td>3.35 (1.11)</td>
<td>10.78 (2.78)</td>
<td>8.26 (2.78)</td>
</tr>
<tr>
<td></td>
<td>(1) condition</td>
<td>(2) time</td>
<td>(2) time</td>
</tr>
<tr>
<td></td>
<td>$F(2, 44) = 18.77^{***}$</td>
<td>$F(1.67, 36.78) = 8.42^{***}$</td>
<td>$F(1.67, 36.78) = 8.42^{***}$</td>
</tr>
<tr>
<td></td>
<td>Mid-treatment</td>
<td>2.35 (1.23)</td>
<td>11.48 (3.74)</td>
</tr>
<tr>
<td></td>
<td>4.00 (1.09)</td>
<td>8.3 (2.64)</td>
<td>8.3 (2.64)</td>
</tr>
<tr>
<td></td>
<td>4.22 (1.09)</td>
<td>7.70 (2.06)</td>
<td>7.70 (2.06)</td>
</tr>
<tr>
<td></td>
<td>(3) interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$F(4.54, 99.95) = 12.93^{***}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-treatment</td>
<td>2.83 (1.40)</td>
<td>11.26 (3.72)</td>
</tr>
<tr>
<td></td>
<td>3.22 (1.04)</td>
<td>9.78 (3.29)</td>
<td>9.78 (3.29)</td>
</tr>
<tr>
<td></td>
<td>3.43 (1.12)</td>
<td>8.61 (1.78)</td>
<td>8.61 (1.78)</td>
</tr>
<tr>
<td></td>
<td>(3) interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$F(6, 132) = 10.89^{***}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>After video clip</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* $P < .05$

** $P < .01$

*** $P < .001$
Note: time 1= baseline; time 2 = mid-treatment; time 3 = post-treatment; time 4 = after watching video clips

Figure 5.2. The effects of a passive, moderate exercise, and vigorous exercise condition on desire to snack

As a follow-up, one-way ANOVAs, were performed at each time-point, namely, mid-treatment, post-treatment, and after watching video clips, followed by paired sample t-test (with Bonferroni correction). There were significant effects of condition at mid-treatment ($F(2, 44) = 13.98, p < 0.001$), post-treatment ($F(1.53, 33.56) = 15.61, p < 0.001$), and after watching video clips ($F(2, 44) = 9.08, p = 0.001$). Desire to snack was significantly lower in the vigorous exercise compared with the passive and moderate exercise condition at mid- (Vigorous vs. Passive: $t(22) = 5.39, p < 0.001$, 95 % confidence interval for difference (CI) 2.43 to 5.38, effect size (ES) $d = 1.16$; Vigorous vs. Moderate: $t(22) = 3.03, p = 0.006$, 95 % CI for difference 0.67 to 3.59, effect size (ES) $d = 0.64$), post-treatment (Vigorous vs. Passive: $t(22) = 4.44, p < 0.001$, 95 % CI 2.16 to 5.93, ES $d = 1.11$; Vigorous vs. Moderate: $t(22) = 4.14, p < 0.001$, 95 % CI for difference 1.24 to 3.72, effect size (ES) $d = 0.69$), and after watching video clips (Vigorous vs. Passive: $t(22) = 3.43, p = 0.002$, 95 % CI 1.01 to 4.12, ES $d = 0.78$; Vigorous vs. Moderate: $t(22) = 3.47, p = 0.002$, 95 % CI for difference 0.77 to 3.06, effect size (ES) $d = 0.55$). Desire to snack was significantly lower in the moderate exercise condition than in the passive condition at mid- ($t(22) = 2.46, p = 0.022$, 95 % CI 0.31 to 3.60, ES $d = 0.53$) and post-treatment ($t(22) = 2.44, p = 0.023$, 95 % CI 0.24 to 2.89, ES $d = 0.42$). After watching video clips, desire to snack in the moderate exercise condition was not significantly different from the passive condition ($t(22) = 1.17, p < 0.05$).

The moderate exercise condition showed significant changes in desire to snack from baseline to mid-treatment ($t(22) = 4.16, p < 0.001$, 95 % CI 1.35 to 4.04, ES $d = 0.81$), and to post-treatment ($t(22) = 4.16, p < 0.001$, 95 % CI 0.47 to 3.18, ES $d = 0.53$), but not after watching video clips.
In the vigorous exercise condition, there were significant changes in desire to snack from baseline to mid-treatment ($t(22) = 6.81, p < 0.001, 95\% \text{ CI} 3.39 \text{ to } 6.35, \text{ ES } d = 1.66$), to post-treatment ($t(22) = 5.54, p < 0.001, 95\% \text{ CI} 2.72 \text{ to } 5.97, \text{ ES } d = 1.42$), and to watching video clips ($t(22) = 3.36, p < 0.01, 95\% \text{ CI} 0.99 \text{ to } 4.22, \text{ ES } d = 0.87$). However, the passive condition did not show any changes over time.

**Hunger (from MPSS)**

Figure 5.3 and Table 5.6 show significant main effects of condition and time and interactive effect of condition × time.

![Graph showing hunger levels](image)

Note: time 1 = baseline; time 2 = mid-treatment; time 3 = post-treatment; time 4 = after watching video clips

**Figure 5.3.** The effects of a passive, moderate exercise, and vigorous exercise condition on hunger

A follow-up test indicated that there were significant differences between conditions at mid-treatment ($F(2, 44) = 7.48, p < 0.01$), post-treatment ($F(1.47, 32.25) = 19.41, p < 0.001$), and after watching video clips ($F(2, 44) = 10.62, p = 0.001$). A paired sample t-test revealed that at mid-treatment hunger was significantly lower in the vigorous exercise condition compared with the passive condition ($t(22) = 3.86, p = 0.001, 95\% \text{ CI} 0.46 \text{ to } 1.54, \text{ ES } d = 0.82$), but was not different from the moderate exercise condition. At post-treatment, in the vigorous exercise condition hunger was significantly lower compared to the passive condition ($t(22) = 5.61, p < .001, 95\% \text{ CI} 0.85 \text{ to } 1.85, \text{ ES } d = 1.23$) and the moderate exercise condition ($t(22) = 3.76, p = 0.001, 95\% \text{ CI} 0.23 \text{ to } 0.81, \text{ ES } d = 0.49$). At this time, in the moderate exercise condition hunger was also significantly lower than the passive condition ($t(22) = 3.22, p = 0.004, 95\% \text{ CI} 0.29 \text{ to } 1.36, \text{ ES } d = 0.69$). After watching snacking video clips, hunger were significantly lower in the vigorous exercise condition compared to the passive condition ($t(22) = 4.04, p = 0.001, 95\% \text{ CI} 0.70, p > 0.05$). In the vigorous exercise condition, there were significant changes in
% CI 0.45 to 1.38, ES $d = 0.83$) and the moderate exercise condition ($t(22) = 3.44, p = 0.002, 95 \% CI 0.23$ to $0.91, ES d = 0.54$).

In the moderate exercise condition there were significant changes in hunger over time from baseline to mid-treatment ($t(22) = 3.73, p = 0.001, 95 \% CI 0.25$ to $0.88, ES d = 0.48$), to post-treatment ($t(22) = 3.69, p = 0.001, 95 \% CI 0.36$ to $1.29, ES d = 0.71$), but not after watching video clips ($t(22) = 2.24, p = 0.04$). In the vigorous exercise condition, there were significant changes in hunger over time from baseline to mid-treatment ($t(22) = 3.89, p = 0.001, 95 \% CI 0.43$ to $1.40, ES d = 0.90$), to post-treatment ($t(22) = 4.72, p < 0.001, 95 \% CI 0.66$ to $1.69, ES d = 1.38$), and to watching video clips ($t(22) = 3.22, p < 0.01, 95 \% CI 0.28$ to $1.29, ES d = 0.91$).

However, in the passive condition no significant change in hunger was shown over time.

**Strength of desire to smoke**

There were significant main effects of condition and time and interactive effect of condition × time, as shown in Figure 5.4 and Table 5.6.

A follow-up test revealed significant differences between conditions at mid-treatment ($F(1.43, 31.40) = 29.95, p < 0.001$), post-treatment ($F(1.19, 26.10) = 30.52, p < 0.001$), after watching video clips ($F(1.54, 33.93) = 21.76, p < 0.001$). Paired sample t-test revealed that at mid-treatment strength of desire to smoke was significantly lower in the vigorous ($t(22) = 5.62, p < 0.001, 95 \% CI 1.26$ to $2.74, ES d = 1.56$) and the moderate exercise condition ($t(22) = 7.65, p < 0.001, 95 \% CI 1.24$ to $2.15, ES d = 1.50$) than in the passive condition. At post-treatment, strength of desire to smoke in the vigorous ($t(22) = 6.05, p < 0.001, 95 \% CI 1.29$ to $2.63, ES d = 1.59$) and the moderate exercise condition ($t(22) = 5.25, p < 0.001, 95 \% CI 1.29$ to $2.63, ES d = 1.37$) were significantly lower compared to the passive condition. After watching video clips, strength of desire to smoke was significantly lower in the vigorous ($t(22) = 5.40, p < 0.001, 95 \% CI 1.07$ to $2.41, ES d = 1.32$) and the moderate exercise condition ($t(22) = 3.53, p = 0.002, 95 \% CI 0.38$ to $1.45, ES d = .69$) compared to the passive condition. Across time points, there was no significant difference between moderate exercise and vigorous exercise, but after watching video clips the two conditions were significantly different ($t(22) = 4.23, p < 0.001, 95 \% CI 0.42$ to $1.23, ES d = .71$).
Strength of desire to smoke significantly decreased in the moderate exercise condition from baseline to mid-treatment ($t(22) = 7.40, p < 0.001, 95\% \text{ CI } 1.19\text{ to } 2.12, \text{ ES } d = 1.57$), to post-treatment ($t(22) = 6.67, p < 0.001, 95\% \text{ CI } 1.20\text{ to } 2.28, \text{ ES } d = 1.60$), but to after watching video clips ($t(22) = 2.52, p = 0.019$). In the vigorous exercise condition, there were significant reductions in strength of desire to smoke from baseline to mid-treatment ($t(22) = 4.89, p < 0.001, 95\% \text{ CI } 0.98\text{ to } 2.42, \text{ ES } d = 1.31$), to post-treatment ($t(22) = 5.62, p < 0.001, 95\% \text{ CI } 1.10\text{ to } 2.38, \text{ ES } d = 1.51$), and to after watching video clips ($t(22) = 3.92, p = 0.001, 95\% \text{ CI } 0.55\text{ to } 1.79, \text{ ES } d = 0.97$). However, in the passive condition no change was shown from baseline to follow-up assessment.

**Affect**

A fully repeated ANOVA revealed significant main effects of condition and time and interactive effect of condition $\times$ time for FS (see Figure 5.5 and Table 5.6).

A follow-up test revealed significant differences between conditions at each time point; mid-treatment ($F(2, 44) = 11.35, p < 0.001$), post-treatment ($F(2, 44) = 4.87, p < 0.05$), and after watching video clips ($F(2, 44) = 4.34, p < 0.05$). A paired sample $t$-test revealed that the vigorous exercise condition showed significantly lower FS than the passive condition ($t(22) = 2.93, p = 0.008, 95\% \text{ CI } 0.34\text{ to } 2.01, \text{ ES } d = 0.69$) and moderate exercise condition ($t(22) = 4.52, p < 0.001, 95\% \text{ CI } 1.01\text{ to } 2.73, \text{ ES } d = 1.18$) at mid-treatment. The moderate exercise condition showed significantly higher FS than the passive condition at post-treatment ($t(22) =$ -
3.27, \( p < 0.01 \), 95 % CI -1.78 to -0.40, ES \( d = 0.63 \)) and after watching video clips \( t(22) = -2.90, \ p < 0.01 \), 95 % CI -1.71 to -0.29, ES \( d = 0.42 \), but no difference compared with vigorous exercise condition. FS significantly decreased in the vigorous exercise condition from baseline to mid-treatment \( t(22) = 4.51, \ p < 0.001 \), 95 % CI 0.82 to 2.22, ES \( d = 0.88 \), but no significant changes from baseline to across time points in the other conditions.

![Graph showing effects of different exercise conditions on FS](image)

Note: time 1= baseline; time 2 = mid-treatment; time 3 = post-treatment; time 4 = after watching video clips

**Figure 5.5.** The effects of a passive, moderate exercise, and vigorous exercise condition on FS

There were significant main effects of condition and interactive effect of condition \( \times \) time for FAS, as shown in Figure 5.6 and Table 5.6.

![Graph showing effects of different exercise conditions on FAS](image)

Note: time 1= baseline; time 2 = mid-treatment; time 3 = post-treatment; time 4 = after watching video clips

**Figure 5.6.** The effects of a passive, moderate exercise, and vigorous exercise condition FAS

In a follow-up test, FAS was significantly different between conditions at mid- \( F(2, 44) = 25.51, \ p < 0.001 \), post-treatment \( F(1.43, 31.42) = 24.46, \ p < 0.001 \), and after watching video
clips \( F(2, 44) = 3.25, p < 0.05 \). Paired sample t-test revealed that FAS in the passive condition was significantly lower than in the moderate and the vigorous exercise condition at mid-
(Passive vs. Moderate: \( t(22) = -6.77, p < 0.001, ES d = 1.93 \); Passive vs. Vigorous: \( t(22) = -5.30, p < 0.001, ES d = 1.67 \)) and post-treatment (Passive vs. Moderate: \( t(22) = -6.88, p < 0.001, ES d = 1.42 \); Passive vs. Vigorous: \( t(22) = -5.00, p < 0.001, ES d = 1.61 \)). However, there was no difference in FAS between the moderate exercise and the vigorous exercise condition at each time point.

FAS increased significantly from baseline to mid-treatment in the moderate and the vigorous exercise condition (Moderate: \( t(22) = -5.79, p < 0.001, ES d = 1.01 \); Vigorous: \( t(22) = -2.34, p < 0.05, ES d = 0.64 \)), and to post-treatment (Moderate: \( t(22) = -3.18, p = 0.004, ES d = 0.79 \); Vigorous: \( t(22) = -2.51, p < 0.05, ES d = 0.79 \)). In the passive condition, FAS was significantly decreased over time from baseline to mid-treatment (\( t(22) = 5.56, p < 0.001, 95 \% CI 0.60 \) to 1.31, \( ES d = 0.82 \)), to post-treatment (\( t(22) = 3.89, p < 0.001, 95 \% CI 0.43 \) to 1.40, \( ES d = 0.73 \)).

**Overall withdrawal symptoms (MPSS)**

There were significant main effects of condition and time and interactive effect of condition ×
time, as shown in Figure 5.7 and Table 5.6.

![Figure 5.7](image)

Note: time 1= baseline; time 2 = mid-treatment; time 3 = post-treatment; time 4 = after watching video
clips

**Figure 5.7.** The effects of a passive, moderate exercise and vigorous exercise condition on
MPSS

A follow-up test showed that there were significant differences between conditions at mid-
treatment \( F(2, 44) = 14.50, p < 0.001 \), post-treatment \( F(1.40, 30.86) = 19.73, p < 0.001 \), and
after watching video clips \((F(2, 44) = 9.68, P < 0.001)\). Paired sample t-tests revealed that MPSS in the passive condition was significantly higher compared to the moderate and the vigorous exercise condition at mid- (Passive vs. Moderate: \(t(22) = 5.12, p < 0.001, ES = 1.03\); Passive vs. Vigorous: \(t(22) = 3.73, p = .001, ES = 0.97\)) and post-treatment (Passive vs. Moderate: \(t(22) = 4.43, p < 0.001, ES = 0.96\); Passive vs. Vigorous: \(t(22) = 4.91, p < 0.001, ES = 1.17\)). However, there was no difference between moderate exercise and vigorous exercise condition at mid- and post-treatment. After watching video clips, MPSS in the passive condition was significantly higher than the vigorous exercise condition \((t(22) = 4.13, p < 0.001, ES = 0.82)\), but no difference compared with moderate exercise condition.

There was a significant reduction in MPSS in the moderate and the vigorous exercise condition over time at each time point from baseline to mid-treatment (Moderate: \(t(22) = 4.75, p < 0.001, 95\%\ CI 1.69 to 4.31, ES = 0.94\); Vigorous: \(t(22) = 3.02, p < 0.01, 95\%\ CI 0.67 to 3.59, ES = 0.84\)), and to post-treatment (Moderate: \((t(22) = 4.32, p < 0.001, 95\%\ CI 1.54 to 4.38, ES = 0.94\)); Vigorous: \((t(22) = 4.12, p < 0.001, 95\%\ CI 1.53 to 4.64, ES = 1.23\)). MPSS in the vigorous exercise condition was significantly lower after watching video clips \((t(22) = 4.40, p < 0.001, 95\%\ CI 1.15 to 3.20, ES = 0.89)\) than baseline. However, there was no significant change in MPSS in the passive condition.

5.3.6. Effects of exercise on attentional bias on snacking and smoking

3 (condition) × 2 (time) fully repeated measures ANOVAs were conducted to examine the effects of exercise on attentional bias on snacking and smoking (see Table 5.7).

*Direction (and %) of initial fixation on snacking images*

There were significant main effects of condition and time and an interactive effect of condition × time for initial fixation on snacking images (See Figure 5.8 and Table 5.7).

The mean (SD) percentage of initial fixation on snacking video clips after treatment for the moderate and the vigorous exercise condition was 51.59% (30.29) and 51.80% (21.67) respectively, and the passive condition was 78.94% (14.39). There were no significant condition differences on percentage of initial fixation at pre-treatment \((p < 0.05)\). At post-treatment, percentage of initial fixation on snacking were lower in the moderate exercise \((t(22) = 5.29, p < 0.001, 95\%\ CI 16.63 to 38.08, ES = 1.04)\) and the vigorous exercise \((t(22) = 6.29, p < 0.001, 95\%\ CI 21.67 to 43.67, ES = 1.23)\).
Table 5.7. Mean (SD), and main and interactive effects of condition and time for attentional bias (% of initial fixations and % of dwell time)

<table>
<thead>
<tr>
<th>Variable (Time)</th>
<th>Condition</th>
<th>Effect (main, interaction)</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passive control</td>
<td>Moderate exercise</td>
<td>Vigorous exercise</td>
</tr>
<tr>
<td>Snacking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% First fixations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>70.07 (24.49)</td>
<td>72.60 (22.42)</td>
<td>67.71 (25.00)</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>78.94 (14.39)</td>
<td>51.59 (30.29)</td>
<td>51.80 (21.67)</td>
</tr>
<tr>
<td>% Dwell time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>62.00 (17.60)</td>
<td>64.90 (14.15)</td>
<td>64.84 (15.66)</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>67.53 (16.46)</td>
<td>59.41 (22.59)</td>
<td>54.86 (22.48)</td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% First fixations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>70.70 (17.96)</td>
<td>64.31 (23.35)</td>
<td>63.25 (17.06)</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>69.58 (21.89)</td>
<td>42.73 (20.09)</td>
<td>45.33 (26.44)</td>
</tr>
<tr>
<td>% Dwell time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>65.45 (17.06)</td>
<td>62.40 (16.66)</td>
<td>65.35 (13.23)</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>67.24 (20.82)</td>
<td>58.62 (20.60)</td>
<td>52.77 (19.14)</td>
</tr>
</tbody>
</table>

* P < .05
** P < .01
*** P < .001
95% CI 18.20 to 36.09, ES $d = 1.42$) compared to the passive condition, however there was no significant difference between two exercise conditions ($t(22) = -0.41, p > .05$).

**Figure 5.8.** The effects of a passive, moderate exercise, and vigorous exercise condition on % of initial fixation on snacking

Post-hoc t-tests revealed that there was a significant reduction on percentage of initial fixation on snacking video clips from pre- to post-treatment in the moderate exercise ($t(22) = 3.04, p = 0.006, 95\% CI 6.67 to 35.37, ES d = 0.77$) and the vigorous exercise condition ($t(22) = 2.62, p = 0.016, 95\% CI 3.32 to 28.49, ES d = 0.68$). However, the passive condition did not show any significant changes from pre- to post-treatment.

**Percentage of dwell time on snacking**

There was a significant interactive effect of condition × time for percentage of dwell time on snacking, but not a main effect for condition or time (See Figure 5.9 and Table 5.7).

**Figure 5.9.** The effects of a passive, moderate exercise, and vigorous exercise condition on % of dwell time on snacking
The mean (SD) percentage of dwell time on snacking video clips after treatment for the passive, the moderate and the vigorous exercise condition was 67.53% (16.46), 59.41% (22.59) and 54.86% (22.48) respectively. There were no significant differences between conditions on percentage of dwell time at pre-treatment, but at post treatment only the vigorous exercise condition was significantly lower than the passive condition ($t(22) = 3.34, p = 0.003$), but not the moderate exercise condition ($p > 0.05$).

Post-hoc t-tests did not find any significant changes in percentage of dwell time from pre- to post-treatment for the passive ($t(22) = -2.42, p = .024$), the moderate ($t(22) = 1.15, p = 0.261$), and the vigorous exercise condition ($t(22) = 2.44, p = 0.023$).

**Direction (and %) of initial fixation to smoking images**

There were significant main effects of condition and time and interactive effect of condition × time for percentage of initial fixation on smoking video clips (See Figure 5.10 and Table 5.7).}

![Figure 5.10](image)

**Figure 5.10.** The effects of a passive, moderate exercise and vigorous exercise condition on % of initial fixation on smoking

The mean (SD) percentage of initial fixation on smoking video clips after treatment for the passive, the moderate, and the vigorous exercise condition was 69.58% (21.89), 42.73% (20.09), 45.33% (26.44), respectively. There were no significant condition differences on percentage of initial fixation at pre-treatment ($p < 0.05$). At post-treatment, percentage of initial fixation on smoking was significantly higher in the passive condition compared to the moderate exercise ($t(22) = 5.42, p < 0.001$) and the vigorous exercise condition ($t(22) = 4.17, p < 0.001$).

Post-hoc t-tests revealed that there was a significant decrease on percentage of initial fixation on smoking video clips from pre- to post-treatment in the moderate exercise ($t(22) = 3.45, p =
0.002), but not in the vigorous exercise condition \((t(22) = 2.59, p = 0.017)\) and the passive condition \((t(22) = 0.22, p > 0.05)\).

**Percentage of dwell time on smoking.**

Figure 5.11 and Table 5.7 shows that there were significant main effects of condition and time and interactive effect of condition \(\times\) time for \(\%\) of dwell time on smoking video clips.

![Graph showing the effects of different exercise conditions on percentage of dwell time on smoking.](image)

**Figure 5.11.** The effects of a passive, moderate exercise and vigorous exercise condition on \(\%\) of dwell time on smoking

There were no significant differences in condition at pre-treatment, but at post-treatment percentage of dwell time on smoking was significantly lower in the vigorous exercise condition than the passive condition \((t(22) = 3.58, p = .002)\).

Post-hoc t-tests reveal that in the vigorous exercise condition \((t(22) = 2.95, p = .007)\) there was a significant decrease in percentage of dwell time on smoking video clips from pre- \((M = 65.35\%, SD = 13.23)\) to post-treatment \((M = 52.77\%, SD = 19.14)\). The passive \((t(22) = -0.66, p > 0.05)\) and the moderate exercise condition \((t(22) = 1.11, P > 0.05)\) did not show any significant changes in percentage of dwell time on smoking video clips from pre- to post-treatment.

The measures of general characteristics (i.e., TFEQ, RS, BIS scales) were added as covariates to all the above ANOVAs, but none had any additional effect on the results.
5.3.7. Associations between change in affect and attentional bias (post-treatment) to snack food images

To examine the relationship between the changes in FS (see Figure 5.5) & FAS (see Figure 5.6) from pre- to post-treatment and attentional bias (post-treatment), a change score was initially calculated. The results shown in Table 5.8 indicate that only following the vigorous intensity exercise were there significant negative correlations between the change in affect (FS & FAS) and attentional bias (% of initial fixation and dwell time) on snack food images. In other words, greater increases in FS and FAS were associated with less attentional bias (both % of initial fixation and dwell time) on snack food.

Table 5.8. Correlation between ∆ FS & FAS and attentional bias measures by conditions

<table>
<thead>
<tr>
<th></th>
<th>snacking</th>
<th>smoking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of initial fixation</td>
<td>% of dwell time</td>
</tr>
<tr>
<td>Passive</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>Δ FS</td>
<td>0.14</td>
<td>-0.28</td>
</tr>
<tr>
<td>Δ FAS</td>
<td>-0.15</td>
<td>0.37</td>
</tr>
<tr>
<td>Mod exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ FS</td>
<td>-0.33</td>
<td>-0.28</td>
</tr>
<tr>
<td>Δ FAS</td>
<td>-0.36</td>
<td>-0.37</td>
</tr>
<tr>
<td>Vig exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ FS</td>
<td>-0.51*</td>
<td>-0.69**</td>
</tr>
<tr>
<td>Δ FAS</td>
<td>-0.42*</td>
<td>-0.43*</td>
</tr>
</tbody>
</table>

Note: Δ FS & ΔFAS = (baseline) – (post-treatment)
* p < 0.05; ** p < 0.01

5.4. Discussion

This is the first study to examine the effects of different intensities of a 15 min bout of exercise on subjective desire to snack and smoke and attentional bias towards snack food and cigarette video clips among temporarily abstinent smokers. During and immediately after a 15 minute bout of both moderate and vigorous intensity exercise, participants reported a significant reduction in both desire to snack and smoke, and attentional bias (% of initial fixations) to snacking and smoking video clips, compared to the passive condition. However, only after vigorous intensity exercise was there a significant reduction in the % of dwell time for snacking and smoking video clips. In other words there were similar findings for the effects of exercise and different intensities on both cravings for snacking and smoking, and on attentional bias.
In terms of desire to snack and hunger, vigorous (compared with the effects of moderate) intensity exercise resulted in greater reductions that lasted longer, as indicated by the effect sizes. A dose-response pattern was not shown for the % of initial fixation measure of attentional bias for snacking, with both intensities resulting in similar reductions. However, only vigorous intensity exercise statistically reduced % of dwell time for snacking videos. Visually, there was a trend towards a dose-response effect, and it may be that there was insufficient statistical power to show this. Further research is needed in which salience and craving for snacking is initially even greater to test the dose-response question.

In terms of strength of desire to smoke, the effects of moderate and vigorous intensity exercise were almost identical, up to the end of treatment, and then the effects were reduced (but were still reduced, compared with the passive condition) following the second visual task (video clips) in the moderate intensity exercise condition. This supports the idea that vigorous exercise may have a longer lasting effect. Given that the scores at baseline indicated only low to moderate cigarette cravings it may be that a flooring effect limited the opportunity to see a dose-response effect of exercise. A dose-response pattern was not shown for the % of initial fixation measure of attentional bias for smoking, with both intensities resulting in similar reductions. However, only vigorous intensity exercise statistically reduced % of dwell time for smoking videos. Visually, there was a trend towards a dose response effect, and it may be that there was insufficient statistical power to show this, or participants did not find cigarettes particularly salient initially to observe a dose-response reducing effect.

Everson and colleagues (2008), showed that both moderate and vigorous intensity exercise were effective in reducing cigarette craving during and post-exercise. Their study was similar to the current study in terms of mode (cycling), exercise duration (with 10 instead of 15 mins), exercise intensity (Moderate = 49.8% HRR and RPE of 12.5, compared with 46% HRR and RPE 12.8 in the present study; Vigorous = 67.9% HRR and RPE of 14.8, compared with 75.5% HRR and RPE 16.7 in the present study) and duration of abstinence. Adjusting for slightly different response formats for subjective cravings (6 vs. 7-point scale) the present study had identical levels of initial cravings (moderately high) to the study by Everson and colleagues. A recent study by Scerbo and colleagues (2010) reported that the effect of running (RPE = 16.2) lasted 10 mins longer than brisk walking (RPE = 13.4), although both intensities reduced the strength of desire to smoke. Participants in Scerbo and colleague’s study had a higher baseline craving (c. 5.5 on a 7-point scale) compared with 4.7 (on a 7-point scale) in Everson’s study, and 2.5 (on a 6-point scale) in the present study. It appeared that a 3 hour abstinence period in the Scerbo study was able to entice smokers with a higher FTND score (4.4, compared with 2.8 in the present study).
Given that the Scerbo study also showed no clear dose-response effect on cravings during and immediately after treatment, even with moderate to high baseline cravings among more dependent smokers, it may be that the results from the present study do indeed reflect that there is little to be gained from vigorous, compared with moderate intensity exercise in terms of reducing cravings and attentional bias. In the present study the second visual task took place between approximately 10 mins post-treatment and it may be that any effects of moderate intensity exercise had dissipated, thus only vigorous intensity exercise resulted in a reduction in attentional bias, in terms of % of dwell time. Further research is need to determine if attentional bias (% of dwell time or maintained attentional bias) is reduced during and immediately following moderate intensity exercise. Nevertheless, the finding that both moderate and vigorous intensity exercise reduced % of initial fixations on smoking images is important. A reduced initial fixation may have relevance in preventing thoughts to intrude when first seeing a smoking related cue. Also, the finding that maintained attentional bias (i.e., over 10 sec video clips) was reduced only after vigorous exercise may suggest that interest in, and salience of, cues are reduced.

In contrast to smoking studies, few studies have investigated the effects of exercise on craving for snack food. The findings in this study support previous studies (Taylor & Oliver, 2009; Thayer et al., 1993) that reported reduced urge to snack after moderate intensity exercise. The present study found that desire to snack was lower during and immediately after both moderate and the vigorous intensity exercise, compared to the passive condition. Avena and colleagues (2008) suggested that food craving may have similar characteristics to craving for addictive substances and may be different from general hunger and food intake. However, in the present study hunger was also suppressed during and after the moderate and the vigorous exercise compared with the passive condition. So it remains unclear if snack food craving is distinct from general hunger, although the effects of exercise on both appear to be similar. Further research is needed in which the effects of exercise on cravings and hunger are compared under satiety and in a state of hunger, although investigating the effects of vigorous exercise, after a recent meal is not likely to result in pleasant symptoms.

In terms of hunger and energy intake, review papers (Martin et al., 2008a; Blundell et al., 2003) reported that most research found that acute exercise did not increase hunger or energy intake, and was able to induce a short-term negative energy balance, despite evidence that vigorous exercise can stimulate hormones such as Ghrelin (Erdmann et al. 2007). Pomerleau and colleagues (2004) compared relative energy intake at lunch following a control condition, low intensity exercise (40% VO₂max), and high intensity exercise (70%VO₂max). They found that the energy intake was lower in both intensities of exercise conditions compared with the control
condition. Moore and colleagues (2004), in a study involving 19 female participants, observed that after exercise participants consumed less food than those in a sedentary group, and that the energy intake was lower after low intensity exercise than after high intensity exercise. Further research is needed to understand how food cravings (particularly for high energy foods) change in response to different intensities of exercise, and if there are any associated hormonal changes.

In food craving research, attentional bias to food cues has been commonly measured by the visual probe task: Greater bias, using this task, has been shown among problematic eating groups such as high External Eaters (Brignell et al., 2009), chocolate craver (Kemps & Tiggemann, 2009), and those in a manipulated negative mood situation (Hepworth et al., 2010). Only a few studies (Nijs et al., 2010; Castellanos et al., 2009) examined attentional bias (gaze direction and duration) by using an eye-tracking system at the same time as the visual dot probe task. Future research could examine the effects of exercise on both direct (using eye tracking technology) and indirect (eg, using the dot probe task) measured simultaneously.

The Incentive-Sensitisation Theory (Robinson & Berridge, 1993; 2008) seems relevant to understanding the findings of the present study. The measure of attentional bias reflects attentional processes which are related to the incentive mechanism (Field & Cox, 2008; Robinson & Berridge, 1993; 2008), and exercise appeared to reduce the tendency for snacking and smoking cues to grab the initial attention of temporarily abstinent smokers. However, the effects on maintained attention are less clear. In a study involving abstinent smokers, Janse Van Rensburg and colleagues (2009a) reported that the subjective desire and maintained attentional bias (time spent gazing or dwell time) towards smoking images decreased following a 15 minute bout of moderate exercise. In contrast the present study showed no effect of moderate intensity exercise on maintained attentional bias. One difference was the use of video clips in the present study compared with still images presented for several seconds by Janse Van Rensburg and colleagues, which may have influenced the results. Also, Janse Van Rensburg and colleagues involved more dependent smokers (FTND score of 4.0) than the present study, and participants had greater baseline cigarette cravings than in the present study. Both of these factors may have contributed to moderate intensity exercise having a greater effect on maintained attention bias (dwell time) than in the present study. Also, Janse Van Rensburg attributed some of the differences in maintained attentional bias between moderate exercise and rest to not only a decrease in bias after exercise but also an increase from pre to post the passive control condition. It may be that sitting doing nothing does little to remove intrusive thoughts, as suggested in the Elaborated Intrusion theory of craving (May et al, 2004), especially after having watched salient images, during an attentional bias task. In the present study there were non-significant increases in dwell time on snacking and smoking images. Having less dependent
smokers with lower cravings may have limited the increase in maintained attentional bias shown by participants from pre to post-control condition.

Field and colleagues (2004) suggested that the initial shift in gaze (i.e., % initial fixation) will be related to trait variables whereas maintenance of gaze or attention (% dwell time) will be associated with state variables. In this study, there were positive moderately strong correlations between percentage of dwell time and desire to snack and strength of desire to smoke at baseline prior to all but one condition. In other words, those participants with higher cravings maintained their attention on the snack and smoking images for a greater proportion of time than those with lower cravings. This may be explained by the ‘wanting’ mechanism from the ‘Incentive Sensitization Theory’ (Robinson & Berridge, 1993). In other words, drug-related stimuli control behaviour as the neural system become sensitised, and ‘wanting’, which is mediated by the neural system, evolves into craving and hence substance seeking.

Previous studies showed the effect of exercise on regulation of mood (Reed & Buck, 2009; Duman, 2005) and on attentional bias through affective changes (Barnes, Coombes, Armstrong, Higgins, & Janelle, 2010). It is possible that the changes of affect may have an important mediating role in the effects of exercise on cravings and attentional bias. Taylor and Oliver (2009) reported a significant correlation between the change in felt arousal and the urge to snack from pre to post moderate intensity exercise. In the present study both moderate and vigorous intensity exercise led to increased affective activation (FAS) and affective valence or pleasure (FS), at the same time as changes in attentional bias. However, only following vigorous intensity exercise were there significant negative correlations between affect change and attentional bias for snack food: But there were no significant correlations between change in affect and attentional bias to smoking images. In terms of intensity of exercise, previous studies by Ekkekakis (Ekkekakis, Hall, Petruzzello, 2008; Ekkekakis & Lind, 2006; Ekkekakis, 2003) have shown variable effects of vigorous exercise on affective valence, but consistently positive affect following moderate exercise. Further studies are needed to investigate the mediating effects of affect on the relationship between exercise and cravings.

**Practical implications**

This is the first study to examine the effect of different intensities of exercise on the different measures of craving towards snacking and smoking related cues among smokers. The findings in this study add to previous findings on the effect of a single session of exercise on self-regulation across a number of addictive behaviours (Oaten & Cheng, 2006; Ussher et al., 2004;
Taylor et al., 2007; Taylor & Oliver, 2009). Few studies have considered the role of exercise as an aid to helping to control cravings for snack foods, and non among regular smokers who are abstinent and may therefore be particularly interested in alternative sources of pleasure from other substances associated with reward. The present study suggests that exercise not only helps to reduce smoking urges and attentional bias, but it also reduces snack food craving and attentional bias among temporarily abstinent smokers. Using short video clips to assess attentional bias rather than still images may increase the generalisability of the findings to natural settings.

Given that smokers gain weight after quitting, and relapse when trying to quit because of weight gain, any intervention that helps with cravings for both cigarettes and snack food during abstinence may be useful. It does seem though that any effects of exercise are fairly short lived. Further studies are needed to determine whether exercise can help with both cravings for both cigarettes and snack food during actual quit attempts, rather than during temporary abstinence.

Regarding the intensity of exercise, both moderate and vigorous intensity exercise appear useful for reducing cigarette and snack food cravings, with the effects lasting longer for vigorous exercise. Vigorous exercise also had greater effects on attentional bias to cigarette and snack food video clips. However, it appears that like previous studies, compared with being inactive even a short period of moderate intensity exercise can have brief beneficial effects on cravings and attentional bias that may otherwise lead to smoking and snacking. It will also be more realistic to ask smokers to do moderate exercise rather than vigorous exercise as smokers tend to be more sedentary (Kaczynski, Manske, Mannell, & Grewal, 2008) and many have poor lung function (Cui et al, 2010).

The recommendations for physical activity for general health is a total of at least 30 minutes a day of at least moderate intensity physical activity on five or more days of the week (Department of Health, 2004). In this study, participants’ physical activity level was lower than the recommendation. Promoting even short bouts of moderate intensity exercise may be useful to accumulate the 30 mins per day but also help to regulate smoking and snacking.

**Research implications**

Several ideas for future research have been mentioned in this Discussion arising from the limitations of the present study. Given that this study is novel in its aims and methods further studies could consider varying the participants involved, the procedures, and measures. The
sample was not strongly nicotine dependent and recruitment of heavier smokers with higher baseline cravings prior to exercise is needed in future studies. In attentional bias research, the visual dot probe task has been used with an eye tracking system (Nijs et al., 2010; Castellanos et al., 2009) and the task consists of a number of trials, including buffer trials and filler trials. In terms of data collection procedures, a further study is needed using more trials of video clips with filler trials to reduce the participants’ awareness of the purpose of the study. Although the order of the video clips and the place (right or left side) of snacking/smoking video clips was presented randomly, the use of only 8 pairs of video clips may have some limitations. The effects of a short bout (15 mins) of exercise in the present study were relative short-live and further research is needed to see if a longer period of exercise would have longer lasting effects.

**Conclusion**

In conclusion, physical activity may help people trying to give up smoking by regulating their desire to snack and smoke. The present study suggests that a brief bout of physical activity may reduce the desire and attentional bias toward snacking and smoking cues during temporary abstinence. It is also suggested that exercise can influence hunger and withdrawal symptoms. Therefore, further research is needed to explore whether physical activity could reduce withdrawal symptoms and support weight control among smokers who are attempting to quit. If a short bout of exercise suppresses the desire to snack and smoke and reduces attentional bias towards snacking and smoking cues then doing as many short bouts of activity may be a useful strategy for weight management and reducing the risk of smoking relapse, especially those afraid of weight gain.
Chapter 6. General Discussion

In this chapter, the key findings of each of 3 studies will be summarised and then the findings will be collectively reviewed and discussed. This discussion will focus on theoretical issues concerning the role of physical activity in self-regulation of addictive behaviours broadly and specifically where food consumption is not driven by appetite and hunger. Methodological and research design issues will be discussed which will consider the link between laboratory based and ecologically valid research, and how the present thesis contributes to the practical understanding of eating behaviours. Finally, there will be a brief reflection of my own personal journey to complete this thesis.

6.1. Summary of each study

The aim of this series of studies was to examine the acute effect of a short bout of exercise on food craving and attentional bias to food snacking among regular chocolate eaters. The summary of the three studies is shown in Table 6.1.

In Study 1 (Chapter 3) eating behaviour was assessed by monitoring *ad libitum* chocolate consumption in a simulated work place involving a low and high challenge task. People who did a 15 min brisk walk consumed less chocolate during breaks in performing a task than those who remained passive. Level of stress did not influence the effect of exercise on chocolate consumption. Arousal (FAS) was higher after the exercise condition and increases in affective activation from pre to post exercise appeared to mediate chocolate consumption.

Study 2 (chapter 4) involved an investigation of the effect of exercise on cravings, hunger, and attentional bias to chocolate images among normal and overweight people, and among short (i.e., 1day) and long-term abstainers (i.e., at least 1week) from chocolate. Attentional bias was indirectly measured by a visual dot probe task. Following a single session of moderate intensity exercise, participants had lower chocolate cravings and less attentional bias to chocolate images (i.e., both of initial and maintained attentional bias) compared with after rest. The effects were similar irrespective of BMI and abstinence period. FS and FAS were higher in the exercise condition than in the passive condition. The effects on FS and FAS were similar irrespective of BMI and abstinence period.
<table>
<thead>
<tr>
<th>Study 1</th>
<th>Participants</th>
<th>Design</th>
<th>Measures</th>
<th>Main outcomes</th>
<th>Other results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = 78 (33M, 45F), age±SD = 24.90±8.15, BMI = 23.56±3.477kg/m²</td>
<td>A 2 x 2 factorial design (exercise vs. rest, high vs. low cognitive challenge)</td>
<td>A 3day diary of chocolate consumption, RPE, Stroop task, ad libitum chocolate eating, FCQ-S/T, FS, FAS, DEBQ (restrained &amp; emotional eating)</td>
<td>Main effect of exercise on total chocolate consumption (F(1, 74) = 7.12, p &lt; .01)</td>
<td>FCQ-S increased after a chocolate cue (F(1,74) = 21.94, p &lt; .001).</td>
</tr>
<tr>
<td></td>
<td>Regular chocolate eaters (100g/d), 2dys abstinence from eating chocolate</td>
<td>Treatment: A 15min moderate intensity exercise (brisk walk on a treadmill) &amp; rest</td>
<td></td>
<td>Positive affect changes (FS &amp; FAS) during &amp; after exercise</td>
<td>Mean (SD) item scores of FCQ-T = 3.65±1.26, DEBQ-RE = 2.44±0.87, DEBQ-EE = 3.03±0.96</td>
</tr>
<tr>
<td>Study 2</td>
<td>N = 58 F, age = 29.64±11.46 (20NW-22.44±1.88 kg/m², 21OW-30.62±4.38 kg/m², 17 Lenter-22.68±2.88 kg/m²)</td>
<td>Countbalanced design</td>
<td>A 4day diary of chocolate consumption with 1dy abstinence, RPE, the Visual Dot Probe Task, hunger &amp; chocolate craving on 100mm VAS, FCCQ-S/T, BIS-11, Go/No Go task, TFEQ-R18, PFS, FS, FAS, the 7-day recall of Physical Activity</td>
<td>Significant interactive effect of condition×time on chocolate craving &amp; hunger (VAS) and main effect of condition on desire to eat chocolate (FCCQ-S), p &lt; .001</td>
<td>Mean (SD) item scores of FCCQ-T = 3.20±0.76, BIS-11 = 2.29±0.31</td>
</tr>
<tr>
<td></td>
<td>Regular chocolate eaters (100g/d), 1dy abstinence from eating chocolate</td>
<td>Treatment: A 15min moderate intensity exercise (brisk walk on a treadmill) &amp; rest</td>
<td></td>
<td>Significant interactive effect of condition×time on total &amp; initial AB, and main effect of condition on maintained AB (p &lt; .05)</td>
<td>Mean (SD) score of PFS = 44.53±11.23, TFEQ-R18 = 45.84±6.28 (UE = 21.84±3.83; EE = 8.43±2.19)</td>
</tr>
<tr>
<td>Study 3</td>
<td>N = 23(15M, 7F), age = 23.96±4.83, 23.47±2.98 kg/m²</td>
<td>Countbalanced design</td>
<td>CO levels, RPE, MPSS, RS, TFEQ-R18 (uncontrolled &amp; emotional eating), PFS, FTND, IPAP, FS, FAS, Eye-tracking technology, FCCQ-S, Strength of desire to smoke</td>
<td>Significant interactive effect of condition×time on FCCQ-S, hunger, strength of desire to smoke (p &lt; .001)</td>
<td>% of HRR = 43.87 (12.77)</td>
</tr>
<tr>
<td></td>
<td>Regular smokers &amp; snackers, 15hr abstinence from smoking</td>
<td>Treatment: A 15min moderate intensity, vigorous intensity exercise (cycle ergometer), rest</td>
<td></td>
<td>Significant interactive effect of condition×time on initial &amp; maintained AB on snacking &amp; smoking (p &lt; .05)</td>
<td>Affectives changes (FS &amp; FAS) during &amp; after exercise</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Initial AB to snack food &amp; cigarette cues were lower after ME &amp; VE than rest</td>
<td></td>
<td>Mean (SD) item scores of BIS-15 = 2.40±0.51</td>
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<td></td>
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<td></td>
<td>Maintained AB to snack food &amp; cigarette cues were lower after VE than rest</td>
<td></td>
<td>Mean (SD) score of PFS = 42.48±11.93, RS = 11.04±5.96, TFEQ-R18 (UE = 22.26±5.07; EE = 6.70±1.94)</td>
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<td>% of HRR = ME 45.82(10.28), VE 75.46(9.38)</td>
</tr>
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</table>

Note. M = males; F = females; NW = normal weight; OW = overweight; RPE = Rating of Perceived Exertion; DEBQ = the Dutch Eating Behaviour Questionnaire; FCQ-S/T – the Food Craving Questionnaire State/Trait; VAS – Visual Analogue Scale; FS – feeling scale; FAS – felt arousal scale; TFEQ-18 – Three-Factor Eating Questionnaire-R18 (UE – Uncontrolled Eating; EE – Emotional Eating); PFS – Power of Food Scale; BIS – Barratt Impulsiveness Scale; RS – Restraint Scale; FTND – the Fagerstrom Test for Nicotine Dependence; AB – attentional bias; ME – moderate intensity exercise; VE – vigorous intensity exercise
Study 3 (chapter 5) assessed the acute effects of different intensities of exercise on subjective cravings and a direct measure of attentional bias to food and smoking images among temporarily abstinent smokers (15hrs) with a tendency for emotional eating. Attentional bias was measured by eye-tracking technology with video clips of snacking and smoking. Both moderate and vigorous intensity exercise reduced subjective cravings and initial attentional bias to both snack food and cigarette images. Participants also spent less time looking at snack food and cigarette video clips (i.e., maintained attentional bias) after vigorous exercise, compared with the rest condition. Affect (FS & FAS) was higher after moderate and vigorous intensity exercise compared with the rest condition.

6.2. Discussion of findings

The following section will consider how the findings in this thesis contribute to the related literature. The findings will be discussed in terms of (1) how the series of studies link together, (2) methodological issues, (3) measurement issues, (4) generalizability of the findings, (5) dose response issues, and (6) theories and mechanisms.

6.2.1. Connection between studies

Previous researchers were interested in the relationship between exercise and eating behaviour with a focus on the effect of exercise on appetite and hunger (review papers: Hopkins et al., 2010; Martins et al., 2008a, 2008b). Compensatory eating has been mostly shown to take place after long and vigorous bouts of exercise (Bozinovski et al., 2009; Erdmann et al., 2007) and previous evidence was not focused on specific groups of people with a tendency to snack. However, the studies in this thesis extended the previous interest to self-regulation of eating (e.g., cravings, automatic and dysregulated eating) while in a state of imposed restraint and in the presence of salient cues (May et al, 2010; Taylor & Oliver, 2009; Thayer et al, 1993; Thayer, 1987).

Study 1 looked at dysregulated eating in a simulated natural setting (i.e., ad libitum eating in the experimental stressed situation) among regular snackers. The idea of this study was to create a simulated workplace and observe actual behaviour. One possible explanation for why exercise reduced snacking was that the participants guessed that they were expected to eat less after exercise. Study 1 also involved a mix of males and females. It has been reported previously that women have a greater tendency of craving high energy snacks and also have greater eating restraint and give up chocolate for Lent. Study 2 thus explored if a measure of attentional bias could detect more subconscious changes in response to exercise and explored attentional bias
among only women who are particularly interested in snacking, including both normal and overweight. Unlike in Study 1, which involved participants who were abstinent for 2 days, Study 2 involved participants who had a similar period of temporary abstinence and also a longer period of self-imposed abstinence (i.e., at least 1 week during Lent).

In Study 2 an automatic response to snack food cues were assessed by an implicit measure (i.e., attentional bias by visual dot probe task) and two subjective craving questionnaires rather than just the use a single explicit measure. Possible explanations for why the effects of moderate intensity exercise were shown only on initial attentional bias, not on maintained attentional bias, were dose of exercise and the limitations of the dot probe task. Thus, based on the previous findings, Study 3 used a different implicit measure (i.e., eye tracker) to measure automatic and maintained response to snack food cues and two different intensities of exercise conditions were used. Following Study 1 and 2, in which background variables (i.e., gender, BMI, abstained period) did not influence the relationship between exercise and food craving/attentional bias, these background variables were not considered as moderators in Study 3. Given that smokers who quit or abstain can experience an increase in hunger and emotional eating, Study 3 involved regular smokers but also regular snackers.

6.2. Methodological issues

6.2.2. Manipulation of cravings

Presenting cues (e.g., smelling, pictures), engaging in mentally challenging tasks (Raspopow et al., 2010; Zellner et al., 2007) and abstaining from substances have been commonly used to manipulate cravings in previous addiction research (Janse Van Rensburg et al., 2009a; Field & Duka, 2004; Jansma et al., 2000). Manipulating craving in an experimental study is important to simulate the situations that may challenge self-regulation. In this thesis it was also important to fully test the potential of exercise to reduce cravings, snacking behaviour, and attentional bias. Thus, in this thesis there were several approaches to manipulate cravings such as abstinence (Study 1, 2, & 3), manipulated-stress (Study 1), and cues (real chocolate cues (Study 1, 2, & Study 3), pictures (Study 2), and videos (Study 3)).

Abstinence. Cravings were manipulated by abstaining from eating chocolate for a certain period. The abstaining periods were varied from 1 day (Study 2), 2 days (Study 1), or at least 1 week (Study 2). In Study 3, smokers were abstained from smoking for 15 hours. Abstinence from addictive substances is commonly used in addiction research. For example, in a smoking study (Field et al., 2004), smokers who abstained from smoking showed greater attentional bias to smoking related images than a non-deprived group. However it is difficult to be confident that
abstaining from chocolate will cause strong craving. Contrary to other substances, foods are not a strongly addictive substance and chocolate could be replaced by other foods (e.g., sweets or other snacks). It was also not easy to confirm abstinence based on only self-report. Unlike smoking studies (i.e., with confirmed expired Carbon Monoxide levels), there is no measure to confirm participants’ abstinence. However, in this thesis, a 3 day chocolate diary with extra days for abstinence (e.g., a 3 day chocolate diary with one day abstinence) was used rather than simply asking participants to confirm abstinence. Every participant successfully completed the diary and submitted prior to each laboratory session. Participants in this thesis were regular and heavy chocolate eaters (e.g., 100g of chocolate a day). For such a heavy chocolate eater abstaining from habitually each chocolate could elicit chocolate craving, especially in the presence of chocolate cues. This enabled the calculation of an estimated time when the last chocolate was eaten but other ways to capture this should be explored in the future. For example, self-reported cravings could be assessed regular intervals during the days before and after abstinence and linked to the time when the last chocolate was eaten.

In the present studies participants who abstained from eating chocolate showed higher baseline attentional bias compared to other studies. For example, Nijs and colleagues (2010) assessed attentional bias measured by a dot probe task (100ms and 500ms cue-presentation time) among normal and overweight females in a state of hunger (fasting for 17 hrs) and satiety. Fasted overweight females showed higher attentional bias to food cues (18.00 for 100ms, 7.26 for 500ms) than those in the satiety condition (6.76 for 100ms, 5.13 for 500ms). Fasted normal weight females also showed higher attentional bias to food cues (8.03 for 100ms, 6.80 for 500ms) than those in the satiety condition (4.98 for 100ms, 5.62 for 500ms). Compared to their study, in Study 2, participants who abstained from eating chocolate for 24 hrs showed higher attentional bias to chocolate images at baseline. In this study, overweight females also showed higher attentional bias to chocolate images (18.27 for 200ms, 32.86 for 1000ms) then normal weight abstainers (14.69 for 200ms, 10.46 for 1000ms), possibly suggesting that the overweight found it more difficult to keep their thoughts or impulses off chocolate.

Manipulated-stress. Study 1 created different levels of stress by involving participants in a fast or slow speed of inter-stimulus period during the Stroop task: This was expected to lead to different levels of consumption. Despite expectations from previous studies (Wallis & Hetherington, 2004; Lattimore, 2001) and differences in the self-reported perceived task demands, the results did not show any effect of manipulated stress on chocolate consumption. The failure to manipulating consumption by stress can be explained by the fact that participants may have mainly focused on success or failure of the task and may not have had enough time to be attracted by chocolate cues. Another possibility is that the Stroop task may not have been powerful enough to elicit a particularly high level of stress. The task did not threaten
participants’ ego as participants did not get any feedback about their performance at the end of each block of the task. Also low challenge may have led to increased eating (from boredom) and high stress may have led to increased eating (to increase pleasure), thus both had similar eating behaviour.

Cues. Cravings were also manipulated by exposure to food-related cues or images. In Study 1, craving was manipulated by placing a bowl of chocolate beside a computer, and also asking participants to unwrap a personally selected chocolate bar. With a real chocolate cue, chocolate consumption was higher in the control group (compared with the exercise group) and chocolate cravings were later increased from pre to post-unwrapping a chocolate bar (in both groups). Looking at images of chocolate in Study 2 and videos of snacks in Study 3 may have elicited an increase in cravings. After exposure to cues participants in the control conditions showed tendencies to increase attentional bias and cravings. Both studies also showed quite high cue-elicited craving at baseline after initial exposure to cues (e.g., mean scores were between 9.00 and 10.70 from FCCQ-S scoring between 3 to 15).

As suggested in a ‘Schematic diagram of brain processing’ (Rolls, 2007, see Figure 2.8 in Chapter 2), in this thesis, sensory factors (e.g., smell, sight), cognitive factors, and satiety/hunger signals (e.g., hunger for chocolate) produce reward value and increase appetite, and as a result, in combination, an increase in chocolate craving. The Elaborated Intrusion Theory (Kavanagh, Andrade, & May, 2005) suggests that an intrusive thought about a cue presented throughout the experimental session may have elicited craving about the food. May and colleagues (2010) added further explanation that physiological deficit, negative affect, external cues, cognitive activity, and anticipatory responses to the target can trigger the spontaneous target-related thought, which is related to craving.

6.2.2.2. Engaging participants in exercise (monitoring issues)

All studies in the thesis used a self-paced bout of exercise and monitored the level of exercise intensity by HR and RPE. The RPE scale was used to roughly set intensity, but also give participants a degree of control because that elicits greater affect (Williams, 2008). From HR data, % of HRR was calculated and it showed a degree of comparability of intensity during moderate exercise across the three studies. In Study 1, % of HRR for moderate intensity exercise was slightly lower (28.78%) than the other studies, but both Study 2 and Study 3 showed similar levels for moderate intensity, 43.87% and 45.82% respectively. The mean RPE scores were also similar in Study 2 (12.51) and Study 3 (12.79), but the RPE was not recorded in Study 1. The difference in intensity between Study 1 and the other studies may be explained by recording RPE and subjective characteristics. Unlike the other studies, in Study 1 RPE scores
were not recorded each 3mins. It may be possible that participants may have not actually kept the same range of RPE for 15mins, although they were instructed to do so. Another possibility to explain the difference is subjective characteristics (e.g., BMI). In Study 2, in spite of the similar level of self-reported RPE, the mean % of HRR was different between 3 groups: The overweight group showed higher % of HRR than the normal weight and the Lent groups.

Measuring fitness would enable a more precise way to set and estimate exercise intensity (King, Miyashita, Wasse, & Stensel, 2010a), but wearing a gas exchange mask would have reduced the generalizability of the findings to natural exercising behaviour. Normally, one could do a VO\textsubscript{2}max test in an initial session then monitor HR during sessions to determine % VO\textsubscript{2}max, but this would have added a burden in terms of time and may have limited recruitment.

6.2.3. Measurement issues in assessing eating-related constructs

6.2.3.1. Self-reported measures for craving

There are several questionnaires to measure state food cravings such as the State Food Craving Questionnaires (FCQ-S) and the Visual Analogue Scale (VAS). The details of measures of food and pros and cons of each measure were discussed in Chapter 2 (see 2.4.2).

The only previous study on the effects of exercise on chocolate cravings (Taylor & Oliver, 2009) used the State Food Chocolate-Craving Questionnaire (FCCQ-S) to assess chocolate craving. Appetite and hunger on a 100mm VAS has been used in previous studies to assess the effect of exercise on appetite (King et al., 2010a, 2010b, Schneider et al., 2009). Studies in this thesis used FCCQ-S and VAS for craving and hunger, and hunger as an item in the Mood and Physical Symptoms Scale (MPSS) (in Study 3), giving an opportunity to compare them. A hunger item was used in Study 2 and 3 and it was to examine whether hunger has a different pattern from other cravings. Hunger has been commonly used in previous studies (King et al., 2010a; 2010b; Hepworth et al., 2010) and it has been reported that hunger is associated with attentional bias to food cues (Tapper et al., 2010). Compared to King and colleagues’ study (2010b), at baseline mean hunger level (using a 100mm VAS) was lower in Study 2 (control=38.6±27.2; exercise=38.9±26.2) than in their study (control=55±7; exercise=58±6).

King and colleagues’ study (2010b) did not show any interactive effect of condition (exercise and no-exercise) and time on hunger, although there was a tendency for a decrease in hunger level after brisk-walking. Contrary to their findings, Study 2 and 3 showed a significant interaction between condition and time, and hunger was significantly lower after exercise than after rest. These effects were also observed with the other craving measures (FCCQ-S and
VAS). It seems that participants may not easily distinguish between physical hunger and cravings, as their responses on the VAS to the two questions were similar. Correlation analysis in Study 2 showed that the three questionnaires (i.e., FCCQ-S, craving on the VAS, and hunger on the VAS) were significantly correlated (with coefficient between 0.66 and 0.83) each other and showed common effects of exercise compared to rest condition. From the results, it is difficult to say if one measure is better than another.

6.2.3.2. Attentional bias

The idea of measuring attentional bias was based on The Incentive Sensitisation Theory (Robinson & Berridge, 1993) and it is hypothesised that an automatic response to the cues may be associated with automatic eating behaviour (habitual behaviour) and maintained response to the cues may reflect a sensitised motivational response. The widely used measure of attentional bias early in the research was a modified version of Stroop task (see a review paper by Field et al., 2009). Many addiction studies have since used the visual dot probe task (Ahern et al., 2010) and eye tracking technology with visual stimuli (Waters et al., 2003; Bonitz & Gordon, 2008). In this thesis, attentional bias was measured in two different ways: indirectly (i.e., visual dot probe task) in Study 2 and directly (i.e., eye tracker) in Study 3. Both initial and maintained attentional bias were assessed using direct and indirect measures. Initial attentional bias was determined from reaction time data at image offset with a shorter duration of the stimuli (dot probe task) or by the percentage of the first eye movement on images (eye tracker). Maintained attentional bias was inferred from reaction time data at image offset with a longer duration of the stimuli (dot probe task) or by the duration of gaze on images (eye tracker). As a measure of attentional bias, it has been suggested that eye tracking data may be more precise and sensitive, and more strongly related to self-reported cravings (Field et al., 2004).

There are some unsolved issues of using the visual dot probe task. The duration of cue-presentation is quite problematic. It has been reported that multiple shifts of attention between stimuli are possible when stimuli are presented for a longer duration (i.e., 500ms or more) (Field & Cox, 2008). In other words, it is difficult to conclude that participants spent more time looking at snack food-related cues, and the attentional bias data only implies that the participants’ attention was directed to the cues at the moment of the cue offset and dot onset. It is also possible that participants looked at an image by chance when the duration of cue-presentation was short. In this situation it will be difficult to recognise the image.

An eye tracker has been commonly used with still images in the appetite and addiction studies (Nijs et al., 2010; Castellanos et al., 2009; Bradley et al., 2007; Field et al., 2004), however in Study 3, pairs of video clips were used as stimuli. According to Elaborated Intrusion Theory
(Kavanagh et al., 2005), imagery and vividness of cues play an important role in craving. In the real world, we are exposed to various types of stimuli such as pictures, cues in a film, and seeing other peoples’ behaviour. Participants in Study 2 also mentioned that they ate chocolates in a social gathering situation and wanted the chocolate when seeing other’s eating behaviour. There have been a few studies using moving cues (i.e., films) in smoking research (Shmueli, Prochaska, & Glantz, 2010; Sargent, Morgenstern, Isensee, & Hanewinkel, 2009; Tong, Bovbjerg, & Erblich, 2007), but they did not provide simultaneously presented matched neutral and smoking images. The possible reason for not using video clips is the difficulty in capturing eye movement while watching moving images. However, to diminish the problem, in Study 3 the pairs of video clips were matched with neutral images by considering their shape, size, luminescence, background, moving speed of images. In addition, considering that the first fixation happened within a short period (e.g., at least 100ms), a still image was presented for 1000ms and the image was then linked to the video clip.

Overall, the findings in this thesis indicate that exercise has an effect on attentional bias using both ways of measuring. No study has previously examined the effect of exercise on attentional bias to snack food cues, but a previous smoking study with still images (Janse Van Rensburg et al., 2009a) showed similar effects of exercise. In addition, the pattern of changes in attentional bias (both measures of attentional bias) following exercise were the same as the changes in subjective craving in this thesis and the previous chocolate craving study (Taylor & Oliver, 2009). In Study 3, video clips appeared meaningful in terms of simulation of natural cues. However, it may not be necessary to use video clips and if still images can save preparation time and time for analysing data. Since this was the first trial to examine the acute effect of exercise on attentional bias using video clips, further studies using video clips may be worthwhile.

6.2.3.3. Relation between self-reported craving and attentional bias

In Study 2 and Study 3, correlations were not shown between self-reported craving and attentional bias, although the results showed that self-reported craving and attentional bias commonly reduced following exercise. There are few studies like the present research that have used two subjective and objective measures together (Hepworth et al., 2010; Janse Van Rensburg et al., 2009a). Hepworth and colleagues (2010) found a small correlation between attentional bias using the dot probe task and subjective appetite (on a 100mm-VAS). With eye-tracking data, Janse Van Rensburg and colleagues (2009a) found that subjective desire to smoke was correlated with initial attentional bias in the control condition, but not in the exercise condition and there was no correlation with maintained attentional bias. Field and colleagues (2009) suggested, with theoretical support, based on ‘Incentive-Sensitization Theory’ (Robinson
& Berridge, 1993) and the Elaborated Intrusion Theory (Kavanagh et al., 2005), that subjective craving and attentional bias are expected to be correlated as they assess the same underlying process. The theories, predicting that cues grab addict’s attention, focus on the majority of common circumstances between subjective craving and attentional bias (Field et al., 2009). However, in correlation analyses, it may be difficult to find a significant correlation between two measures as they measure different things (i.e., behavioural process or motivation process to consume).

In the context of cue-reactivity research, Perkins (2009) pointed out a weak relationship between self-reported craving (cue-reactivity) and behaviour (e.g., smoking behaviour, relapse), and that abstinence-induced craving (not cue-induced craving) is more likely to predict the relapse risk. However, Shiffman (2009) commented on Perkins’ arguments and stated that most relapse episodes occur during cue exposure and cue-provoked craving. Thus, in this thesis, to minimise these issues, participants in each study abstained from eating chocolate for at least 24 hours and their cravings were measured after exposure to cues. The cravings tended to be increased by cues in the control condition across three studies in this thesis and also in the previous research (Janse Van Rensburg et al., 2009a). However, as suggested by Perkins, further investigations are needed to examine whether cue-induced craving predicts actual behaviour.

6.2.3.4. Liking and wanting issues with outcome measures

Berridge (1996, 2009), based on the Incentive-Sensitization Theory, stated that two reward components, ‘liking’ and ‘wanting’, are controlled by different brain mechanism (under the control of opioid vs. dopamine). The former is related to a hedonic/affective reaction and the latter refers to the motivation to eat/craving (motivational incentive salience) (see section 2.1.3 in Chapter 2). Some studies tried to dissociate these concepts in a laboratory based setting (Finlayson et al., 2007a; Lemmens et al., 2011) by using palatability questions and a computer based wanting task. This thesis did not assess liking (palatability of food) and mainly focused on motivational incentive salience to cues. Although participants were not hungry (e.g., in Study 2 they were asked to eat between 2-3 hours before testing), the craving and attentional bias data showed that their motivation to eat (‘wanting’) was increased when they were exposed to cues and exercise attenuated the effect. This may imply that exercise has an important role to self-regulate ‘wanting’ to snack food.
6.2.4. Generalizability of the findings

6.2.4.1. Recruitment issues

Participants were recruited via several approaches aimed to maximise the generalisability of the findings, rather than recruiting participants only from University populations which has been common in previous studies (Kemps, Tiggemann, & Grigg, 2008; Kemps & Tiggemann, 2007; Tiggemann & Kemps, 2005). For example, in previous studies, the mean and SD of age were limited between 20 and 22 (e.g., Kemps et al., 2008 = 21.43 ±3.05; Franken & Muris, 2005 = 20.2 ±2.1). For this thesis, the research advertisements were placed in public places (e.g., train station, bus stop, laundry shop), web broadcast (e.g., Gumtree, University noticeboard), education institution (e.g., University of Exeter, Exeter college, nursery school & primary school for parents who are waiting for their children), chocolate society, weight-loss group, and supermarkets in Exeter. E-mails were also sent through University networks to anyone who had a University-email account (e.g., students, staffs). The flyers were also placed in chocolate shops and on litter bins where chocolate eaters may throw away wrappers. Information that participants would get paid at the end of session with the amount of money was shown on recruitment advertisements. Incentives are commonly used to recruit participants but it can also reduce generalizability by only attracting those with spare time who need the money (e.g., students). However, overall, in this thesis, participants were recruited across a wide range of ages and occupations. The mean ± SD of age was 24.90 ± 8.15 in Study 1, 29.64 ±11.46 in Study 2, and 23.96 ± 4.83 in Study 3 with a range of between 18 and 55.

6.2.4.2. Characteristics of the samples across three studies

Participants in this thesis were recruited from a variety of different groups across age, gender, BMI, and abstaining periods (see Table 6.1). In Study 1 and 3, participants were mixed gender and normal weight and in Study 2 they were only females and normal and overweight. Wansink et al. (2003) found that there were gender differences in comfort food preference and females preferred snack food more than males. Overweight/obese people experienced an increased desire to eat and produce more saliva after exposure to food cues (Ferriday & Brunstrom, 2010) and they seemed to have a greater attentional bias to food images when they are hungry (Nijs et al., 2010). Study 2 showed that overweight participants had higher trait chocolate craving than normal weight and longer abstainers were higher than temporary abstainers. Study 3 did not measure trait chocolate craving, but the mean (SD) item scores of trait chocolate craving (FCQ-T) was 3.6 ± 1.3 and 3.20 ± 0.76 for Study 1 and 2, respectively, which indicated moderately high cravings. In a study by Rodriguez (2005), high chocolate cravers reported 3.86 (0.54) and non-cravers showed 1.38 (0.19) on the mean (SD) item scores of FCQ-T. Taylor and Oliver
Also found that chocolate cravers reported 3.6 (0.8) on the mean (SD) item scores of FCQ-T.

According to data from the self-reported physical activity questionnaire in Study 2 and 3, in general, participants in this thesis were inactive. Most previous studies concerned with appetite or food craving did not report participants’ physical activity levels, so it is difficult to compare physical activity levels. In Study 2, normal weight females were statistically more active (moderate exercise = 320.00min/week, vigorous exercise = 105.40min/week) than overweight females (moderate exercise = 323.62min/week, vigorous exercise = 38.57min/week). Participants in Study 3 did less than 2 days of moderate and vigorous exercise per week, which means that they can be regarded as inactive people.

The Restrained Eating (RE) score in the Study 1 (DEBQ: the mean item score = 2.44 ± 0.87) was similar to other normal healthy adults (Muller et al., 2008; RE = 2.4 ± 0.8; Kemps & Tiggemann, 2009; chocolate craver = 2.82 ± 1.07; non-chocolate craver = 2.78 ± 1.09). The RE score in Study 2 (TFEQ-18: 15.57 ± 3.48) was slightly higher than other adult samples in the UK (Keskitalo et al., 2008; 13.4 ± 3.6). Those in Study 3 (RS: 11.04 ± 5.96) were similar to other chocolate cravers (Smeets et al, 2009; chocolate craver-exposure to chocolate cue = 10.94 ± 4.02, chocolate craver-non exposure to the cue = 11.53±3.43). Overall, participants’ RE scores were moderately high and were similar to other chocolate craver groups.

Impulsivity has been reported as an important predictor of health related behaviour (e.g., alcohol consumption, smoking, compulsive eating) (see reviews, Hofmann et al., 2008; Davis & Carter, 2009; Reynolds et al., 2007). Guerrieri et al. (2007) found that higher impulsive people ate more sweets compared to low impulsive people. In their study, the mean (± SD) score on the BIS-11 for a high impulsive group was 2.48 ± 0.28 and for low impulsive group was 1.97 ± 0.27. Scores for impulsivity in this thesis were 2.29 ± 0.31 in Study 2 and 2.4 ± 0.51 in Study 3, which are comparable.

An aim of this thesis was to determine if any effects of exercise on eating-related variables would be moderated by any sample characteristics. Across the three studies in this thesis, the effects of exercise on outcome variables (cravings, hunger, and attentional bias) did not differ when background and trait variables were added as covariates. The findings imply that the effects of exercise on food craving could be generalizable to regular snackers with a range of participant characteristics.
6.2.5. Dose response issues

In previous exercise and eating-related studies, there has been no study comparing different intensities of exercise on outcomes. In this thesis, Study 1 and Study 2 examined the effect of moderate intensity exercise on food craving and Study 3 compared the effect of moderate and vigorous intensity exercise on craving and attentional bias. Overall, it was concluded that both intensities of exercise reduced cravings and attentional bias to snack-related food cues compared with after inactivity, although the reduction from pre to post exercise was bigger after vigorous exercise.

In research with smokers, Everson and colleagues (2008) compared the effect of 10mins of moderate exercise and vigorous exercise on desire to smoke and withdrawal symptoms. They found that both intensities of exercise alleviated desire to smoke, but only moderate intensity exercise reduced withdrawal symptoms. Scerbo and colleagues (2010) examined the effects of exercise on cigarette cravings with three conditions (i.e., control, walking, and running). They also found significant reductions in craving to smoke after both intensities of exercise compared with control condition, with no difference between moderate and vigorous intensity exercise. Although both intensities reduced the desire to smoke, they reported that the effect of the vigorous intensity exercise lasted longer than the moderate intensity exercise.

In snacking research, Taylor and Oliver (2009) and Thayer and colleagues (1993a) found that a short bout of moderate intensity exercise reduced snack-food craving. The series of studies from Study 1 to Study 3 support the previous findings that a short bout of moderate intensity exercise reduced chocolate/snack craving. Self-paced moderate intensity exercise is more related to a positive affective response compared with vigorous exercise, and this may lead to better adherence (Williams, 2008). A clear mechanism by which exercise enhances positive affect and in turn reduces cravings has yet to be fully supported. It may be useful information for people with addictions if a short bout of moderate intensity exercise can achieve the same benefits as vigorous exercise.

6.2.6. Theories and mechanisms

It is well-known that exercise may acutely improve self-regulation of appetite (see a review, Martins et al., 2008a), smoking (Taylor et al., 2007), and alcohol (Ussher et al., 2004). Oaten and Chen (2006) reported that regular physical exercise (a 2 month programme) improved self-regulatory capacity (e.g., decreases in perceived stress, emotional distress, smoking, alcohol, and caffeine consumption). The present series of studies found that exercise reduced food cravings and attentional bias to snack related foods. The effect of exercise on self-regulation of
snacking may be explained by several potential mechanisms (see 2.5 in Chapter 2) but I will focus on hunger/appetite, affect, exercise as a distractor, and expectancy about exercise.

**Hunger/appetite.** Reduction in craving and attentional bias may be explained by a decrease in hunger and appetite. Study 2 and Study 3 showed a reduction in self-report hunger following exercise compared with being passive. Some appetite studies explained the reduction in hunger and appetite after exercise by physiological mechanism (i.e., changes in energy balance hormones, King et al., 2010a; Ueda et al., 2009a, 2009b). However, snacking behaviours frequently occur between meal times (Johnson & Anderson, 2010) and are not linked to biological needs, and food craving is related to reward mechanism (Volkow et al., 2011).

**Affect.** The effects of exercise on cravings and attentional bias may be mediated by changes in affect. Study 1 - 3 commonly showed improvements in affect during and after the exercise session, compared with a passive condition, alongside reduced cravings. The acute effect of exercise on positive-activated affect has been widely reported (e.g., Taylor et al., 2006; Ekkekakis et al., 2000). Across the three studies from Study 1 to 3, mediation analysis did not show any mediating effect of affect on the relationship between exercise and chocolate consumption/cravings. However, in Study 1, there was a slight trend of mediating effect of FAS on the chocolate consumption in a high stress condition. Qualitative findings in Study 2 also revealed that most participants ate chocolate when they were feeling low (e.g., to lift mood, when bored) and when they were deactivated (e.g., low energy, fatigue). This implies that affect was an important factor for snacking.

Eating and exercise are common approaches for mood-regulation (Thayer, 2001; Thayer et al., 1994). Thayer (1987) found that people reported higher self-rated energy and lower tension after walking briskly than after snacking (i.e., eating a candy bar) and the increased activation derived from snacking was short-lived. In another study (Thayer et al., 1993) it was reported that walking increased energy and reduced the urge to snack, and the time to eat the next snack was doubled. Duman (2005), in a review, stated that exercise increases neurotrophic and neurogenesis, and produces antidepressant effects. Considering that both highly palatable food and exercise have hedonic aspects, exercise could replace the role of the snack-foods. Thus, exercise may be useful for heavy chocolate eaters to self-regulate snacking, and with an increase in positive-activated affect consumers may have a reduced need to self-regulate their mood by eating high-caloric foods.

**Distraction.** It is possible that exercise had a distracting effect and subjects could not think about the target-objects (chocolates, snack foods, or cigarettes). Participants may have found it difficult to exercise and thinking about snack foods, compared with being seated with no
distractions. According to the Elaborated Intrusion Theory (Kavanagh et al., 2005), thoughts are intruded by cues and they are elaborated once the users are conscious of the craving. It may be possible to elaborate on snack food-related images while seated and hence a craving or the salience of the substance becomes stronger. In Study 2, total and initial attentional bias was significantly increased from baseline to post-resting, whereas other subjective cravings and attentional bias across three studies were not increased after passively seating. In previous smoking research, Daniel and colleagues (2006) found that cognitive distraction is not the main mechanism producing changes in desire to smoke. Further research is needed to investigate whether the effects of exercise on food cravings are because of cognitive distraction, with an additional attention control condition.

*Expectancy.* Another possible explanation is that expectation about the effect of exercise may be linked to reduce chocolate cravings. Theories related to health behaviours such as The Health Belief Model (Rosenstock, 1966) and The Theory of Planned Behaviour (Azjen, 1985) stress the importance of outcome expectancy (belief) to predict behaviours. Participants who chose to be involve in the study may have been more interested in the role of exercise and have had a positive expectation of its effect (e.g., exercise may help their self-regulation of eating). Their potential belief about the acute effects of exercise on food craving may have influenced their craving following exercise. However, in a smoking study, Daniel and colleagues (2007) found that the expectations about the effect of exercise were not related to the exercise induced reductions in desire to smoke and smoking withdrawal symptoms. Further investigation about the role of outcome expectancy is needed.

*Neuro-cognitive mechanism.* Last but not least, the changes in craving and attentional bias to snack food cues may be explained by a neuro-cognitive mechanism. Janse Van Rensburg, Taylor, Hodgson, and Benattayallah (2009b) examined the effect of exercise on regional brain activation in response to smoking and neutral images using a functional Magnetic Resonance Imaging (fMRI). They found that reward, motivation, and visuo-spatial attention related brain regions were activated after passive sitting, but after exercise there was reduced activation in the dorso-lateral prefrontal cortex and there was a concomitant shift of activation to the “brain default mode” (Broadmanns Area 10). They also found self-reported cigarette craving was lower during and post-exercise compared with being passive. Similar to this smoking study, in terms of addiction, the reduced food craving and attentional bias to snack foods following exercise treatment may occur by a shift in regional brain activation. Further research is needed to investigate the effect of exercise on regional brain activation during exposure to snack food-related cues.
6.3. Limitations and direction for future research

6.3.1. Limitations

The present study has a number of limitations that should be taken into account. Firstly, there could be a self-selection bias in sampling that could make it difficult to generalize the findings to the wider population. While recruiting heavy chocolate cravers, it is expected that they may be inactive and are involved in unhealthy behaviours. However, people who chose to take part in this study may have been more interested in physical activity than a general sample of regular chocolate eaters. Also, payment of participants may have led to a sampling bias. However, Study 2 and Study 3 indicated that participants on average did not meet national physical activity guidelines (i.e., at least 30 minutes, at least 5 days a week).

Secondly, it is not clear to what extent manipulation of cravings can be derived from chocolate deprivation like with cravings for other substances such as cigarettes. In addiction study, cravings for other substances (e.g., cigarette) have been successfully manipulated by abstaining from the substance (Mahler & de Wit, 2010; Everson et al., 2008; Janse Van Rensburg et al., 2009a). Also, earlier in this chapter it is mentioned that Nijs and colleagues (2010) showed attentional bias to food images was greater when participants were hungry than when satiated. This may imply that abstinence influences food interest. In this thesis, before the first session, all participants were asked to abstain from eating chocolate and participants who were abstinent during Lent were asked not to eat any chocolate during the period. Participants’ cravings were only measured after abstinence and not before, as it was assumed that the abstained participants would have high cravings after an abstinence period. However, it was difficult to check whether they really abstained from eating chocolate for the defined period. In further studies cravings could be taken prior to abstinence as in smoking studies (e.g., Ussher, West, Evans, Steptoe, McEwen, Clow, et al., 2006) or it may need a control group who eat chocolate without an abstinence period to confirm that self-reported cravings are increased after abstinence. However, although it is difficult to check deprivation as there is no chemical validation, a chocolate-diary for self-report was used in this thesis.

Thirdly, all three studies involved laboratory-based exercise to control for a range of factors (e.g., intensity of exercise, distraction). It is one of the strengths of doing a laboratory-based study that everybody did exercise in the same setting; however, it also could be a weakness that the exercise may be different from natural forms where there may be other distractions such as weather and social contact. A few studies have shown that there is no difference in the acute effect of exercise on mood between indoor and outdoor sessions (e.g., a systematic review by
Coon, Boddy, Stein, Whear, Barton, & Depledge, 2011), but the quality of evidence was fairly weak.

Fourthly, the salience of cues used in the study is unknown. Real chocolate was used in Study 1 to measure individuals’ snacking behaviour, and in Study 2 and Study 3 images of snack foods were used as cues. It is not clear whether images of food have as strong a salience as real food. However, the results (cue-induced craving) through three studies were consistent and in the study 3 video clips were used rather than still pictures to closely simulate to real cues. Previous studies have also shown that such images (in attentional bias studies) have been associated with subjective cravings and attentional bias in addiction studies (Janse Van Rensburg et al., 2009a, 2009b; Waters et al., 2003; Miller & Fillmore, 2010).

Fifthly, participants’ previous meal time before coming to the lab could not be well controlled. The differences on food craving between a hunger and satiety situation have been reported (Nijs et al., 2010; Mogg, Bradley, Hyare, & Lee, 1998). To distinguish hedonic hunger from biological hunger, the meal time or fullness prior to taking part in the lab-session should be controlled. Study 2 controlled participants’ fullness by asking them to have a normal meal 3 or 4 hours before coming to the lab. In study 3, participants had to abstain from smoking at least 15 hours and for heavy smokers it was easier to abstain overnight and come to the lab in the morning. Considering the further condition that participants were asked to not eat/drink/exercise 2 hours before coming the lab (because of performing exercise), it was hard to control for meal time and biological hunger. Across three studies, participants’ fullness was controlled by asking participants to abstain from eating/drinking (except water)/exercise 2 hours, but their hunger and satiety states were determined from self-report. However, in all the studies, participants were asked to complete each session at the same time to control for diurnal variation across testing sessions.

6.3.2. Further research

This thesis focuses on the acute effect of exercise on food craving (chocolate, snack food) and related constructs. Study 3 investigated smoking and snacking together by examining snacking behaviour among temporarily abstinent smokers. People with one addictive behaviour tend to engage in multiple risky behaviours (Chiolero et al., 2008). As smokers find sweet food as a replacement of cigarette (Logue, 1996), heavy drinkers may find other replacements when they abstain from drinking alcohol.

This thesis focused on sweets rather than savoury snacks. Some people prefer to snack on savoury food (e.g., crisps) more than sweet food. For example, in a survey, young adults in
Egypt more often reported craving for savouries than for sweets (Parker, Kamel, & Zellner, 2003). Torres, Turner, and Nowson (2010) reviewed the relationship between stress and salt intake and found that stress may drive salt intake in animal studies, but there is a need for more evidence in human subject. Thus, further studies are needed to explore the effects of exercise on different types of snack foods, which may also be driven by urges and involve weak self-regulation.

Measurement issues also raise questions for further research. Firstly, Study 1 measured the effects of exercise on ad libitum chocolate consumption, and further research is needed on exercise and ad libitum drinking and smoking. Secondly, the visual dot probe task could be used to assess the effect of exercise on attentional bias in alcohol and smoking studies. Thirdly, qualitative methods could be useful to examine the effect of exercise on self-regulation of eating and other addictive behaviours. In Study 2, the qualitative data played a role to understand participants’ prior motives for eating chocolate. Fifthly, the role of impulsivity needs further investigation. The present studies did not find any role of trait impulsivity in moderating the effects of exercise but further research is needed as other addiction research develops (Papachristou et al., 2011; Carlson et al., 2010). Lastly, further studies could be developed with psychophysiological equipment such as fMRI, NIRS, and EEG. For example, Janse Van Rensburg et al. (2009b) examined the effect of moderate intensity of exercise on cigarette cravings and brain activation in response to smoking-related images by using fMRI.

6.4. Implications

This series of studies may provide practical implications for the prevention of obesity and success of self-regulation of eating. 15 minutes of moderate intensity of exercise appears to reduce snack food cravings and attentional bias to snack-related food cues (e.g., chocolate). A single short bout of exercise is a relatively small amount of physical activity. However, when it is accumulated in a day and reduces the frequency and strength of cravings, in the long-term the results may contribute to not only weight management, but also healthy eating behaviour. Conversely, sedentary behaviour may increase dysregulation of snacking. The repeated successful experience of self-regulation of snacking and cravings may help to enhance an individual’s self-efficacy and motivation to change from unhealthy habitual behaviours to a more balanced diet with less high-energy snacks.
Chapter 7. Conclusion

Food addiction may not be as strong as other drug addictions because food is also related to human basic need (e.g., homeostatic hunger). However, the problem of food addiction (or food craving) is that most craved food is for high energy food (snack foods) which can cause subtle weight gain and failure to gain necessary nutrients from a balanced diet. Recent studies have reported that addiction to certain types of food may share the same brain reward pathway (Grosshans et al., 2011) and have similar features (Avena et al., 2008) as other substance-related addiction. Categorising high energy snack food in a similar way as addictive substances such as tobacco or alcohol may or may not be appropriate. However, for some people who have lower self-control capacity or ability to self-regulate, the repeated and frequent craving for this type of food could lead to the development of an automatic and dysregulated eating pattern when they are stimulated by food cues, and such dysregulation may be also increased by being sedentary.

The findings in the series of studies in this thesis provide support for the predictions of problematic behaviour which is caused by stimuli, and suggest that a single bout of exercise can help to acutely control food craving and attentional bias to food-related cues. These findings were evident in various groups of regular chocolate eaters and were irrespective of the type and intensity of exercise. It may be a helpful finding for some people who feel difficulty to start exercise (e.g., sedentary people) that a 15 minute-moderate intensity of exercise (e.g., brisk walking) reduced food craving. The small amount of physical activity is easy to achieve every day, and repeated successful experience of controlling their craving could improve their eating habits and contribute to weight management. Furthermore, this successful self-regulation may improve other multiple behaviours (e.g., smoking, drinking alcohol).

The national guidelines for accumulating 30mins of moderate intensity physical activity each day fits well with the present thesis in that not only can multiple short bout of physical activity reduces risk of Type 2 diabetes and other health outcomes, but it may help to self-regulate snacking among smokers and non-smokers, normal and overweight, and those abstaining for shorter and longer periods.

To sum up, this thesis does suggest that being physically active appears to help to enhance self-control capacity and self-regulation in the presence of cues that are salient and likely to grab interest. For the first time this thesis provides evidence of the effects of exercise on craving and attentional bias to snack food-related cues and may support the idea that food craving and salience has similarities to other addictive behaviours, in which self-regulation and control of non-reflective actions is a challenge.
References


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Appendix

Appendix 1. Information sheet for Study 1, 2, and 3.

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PARTICIPANT INFORMATION SHEET

Please read this information sheet carefully. You are invited to take part in a research study but firstly, it is important for you to understand why the research is being done and what it will involve. If you are uncertain about any aspect of the study, you are encouraged to contact the researcher using the information given below, who will be happy to clarify any uncertainties. Take time to decide whether or not you wish to take part.

What is the purpose of the study?
The aim of the study is to examine the effects of a short bout of exercise on cognitive performance, and preference for chocolate.

Who can participate?
Any male or female between the ages of 18-50 years, who is not pregnant, is not receiving psychiatric treatment or suffering from an injury, disease or symptoms of disease (including heart disease, chest pain, dizziness or fainting, bone or joint problems), which may be exaggerated by moderate intensity exercise. Please let us know if you have any food allergies. You will be asked some initial questions about your chocolate consumption to determine your suitability for the study.

What does the study involve?
First you will have to not eat chocolate for 3 days. Then, we would like you to come to our laboratory, on the St Luke’s Campus, for a testing session lasting no longer than 40 mins. You will asked not to eat, drink (except water) and avoid exercise for 3 hours beforehand. At the laboratory, you will fill out an Informed Consent Form.

You will do 15 minutes of brisk treadmill walking or passive seating, before completing simple psychological tests. After the psychological test you will be asked some questions about chocolate and allowed to eat some.

You have the right to withdraw from the study at any time without disadvantage. All information that is collected about you during the course of the research will remain confidential and will be coded to protect identity. Data is available to you at any time on request. Your identity will not be revealed in any publication of the results.

If you have any enquiries please do not hesitate to contact myself (Hwajung, Oh) on 07891865371 (hjo203@exeter.ac.uk) or the research supervisor, Professor Adrian Taylor on 01392-264747 (A.H.Taylor@exeter.ac.uk).

Thank you very much for taking time to consider this invitation.
PARTICIPANTS INFORMATION SHEET

How does exercise affect mental performance among regular chocolate eaters?

You are asked to read this information sheet carefully. You are invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. If you are uncertain about any aspect of the study, you are encouraged to contact the researcher (see contact details below), who will be happy to clarify any uncertainties. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

The aim of the study is to examine the effects of a short bout of moderate exercise versus rest on physiological and psychological responses to chocolate cues.

Who can participate?

Any female between the ages of 18-45 years, who is not overweight (Body Mass Index <25) [replace with: ‘is obese (BMI >30)’ on a different P.I.S.], they can safely exercise at a moderate intensity on a treadmill (according to the SHS Physical Activity Readiness Questionnaire), and be a regular chocolate eater (i.e., at least 100g of chocolate per day such as 1 big chocolate bar).

What does the study involve?

Firstly, you will be asked to record a 3-day chocolate diary, then not eat chocolate for one day before coming to our laboratory on the St Luke’s Campus, for one 60 min and one 45 minute testing session. On each day you come to the laboratory you must eat your normal meal (i.e, breakfast, lunch), then not eat, drink (except water) and avoid exercise for 2 hours before arriving at the laboratory. Upon arrival at the laboratory, you will be required to fill out an Informed Consent Form. You will wear a heart rate monitor and complete some questionnaires during your visit. It is important that you wear comfortable clothing and footwear that will allow you to perform exercise safely.

At each session you will be assigned to a 15 minute period of passive seating or brisk walking on a treadmill. Before and after rest or exercise you will complete simple psychological tests at a computer terminal, and then be asked some questions about mood and eating.

You have the right to withdraw from the study at anytime without disadvantage. All information that is collected about you during the course of the research will remain confidential and will be coded to protect subject identity. Data is available to you at any time on request. Your identity will not be revealed in any publication of the results. At the completion of the two sessions you will be eligible to receive £12 remuneration for your time and expenses.

If you have any enquiries please do not hesitate to contact myself (Hwajung, Oh) on 07891865371 (hjo203@exeter.ac.uk) or the research supervisor, Professor Adrian Taylor on 01392-264747 (A.H.Taylor@exeter.ac.uk).

Thank you very much for taking time to consider this invitation.
SCHOOL OF SPORT AND HEALTH SCIENCES
PARTICIPANTS INFORMATION SHEET

The effects of exercise on interest in food among abstinent smokers

You are asked to read this information sheet carefully. You are invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. If you are uncertain about any aspect of the study, you are encouraged to contact the researcher (see contact details below), who will be happy to clarify any uncertainties. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

The aim of the study is to examine the effects of a short bout of exercise (at moderate and vigorous intensity) versus rest on physiological and psychological responses to snacking and smoking cues.

Who can participate?

Any male or female between the ages of 18-45 years, who is not pregnant, does not receive psychiatric treatment or suffer from an injury, disease or symptoms of disease (including heart disease, chest pain, dizziness or fainting, bone or joint problems), which may be exaggerated by moderate or vigorous intensity exercise (cycling), and regular exerciser (undertaking at least 150 mins of moderate or vigorous physical activity per week). Also, participants should have smoked at least 10 cigarettes a day (for the last 2 or more years) and snack frequently, and are not currently attempting to quit smoking. For health and safety reasons, participants are asked to complete some screening questionnaires, and finger prick blood test to check cholesterol and blood glucose.

What does the study involve?

We would like you to come to our laboratory, for around an initial 60 min and two 45 minute testing sessions on separate occasions. Firstly, you will be asked to abstain from smoking for 15 hours before each session. This is important to the experiment and must be confirmed with a smoke analyser in the lab before the experiment. Secondly, you are requested not to eat, drink (except water) and avoid exercise for 2 hours before arriving at the laboratory. Upon arrival at the laboratory, you will be required to fill out an Informed Consent Form. You will wear a heart rate monitor and complete some questionnaires during your visit. It is important that you wear comfortable clothing and footwear that will allow you to perform exercise safely.

At each session you will be assigned to a 15 minute treatment period of passive seating or cycling on a cycle ergometer. In the two sessions involving exercise, one will require you to cycle at a light-moderate intensity and one at a hard intensity for 15 mins. Before and after the treatment, you will view images for food, cigarettes, and neutral pictures, while wearing eye tracking technology to capture your eye movements. Therefore, you are asked to avoid wearing make-up, especially oil based products around the eyes. You will then be asked some questions about eating and smoking.

You have the right to withdraw from the study at anytime without disadvantage. All information that is collected about you during the course of the research will remain confidential and will be coded to protect subject identity. Data is available to you at any time on request. Your identity will not be revealed in any publication of the results.

If you have any enquiries please do not hesitate to contact myself (Hwajung, Oh) on 07891865371 (hjo203@exeter.ac.uk) or the research supervisor, Professor Adrian Taylor on 01392-264747 (A.H.Taylor@exeter.ac.uk).

Thank you very much for taking time to consider this invitation.
Appendix 2. Stroop task

BLUE

BLUE RED GREEN
Appendix 3. Questionnaires for Study 1

ID:________________________  Time:________________________

**The Dutch Eating Behaviour Questionnaire**

*Below are some questions about your eating habits. There are no right or wrong answers. Please answer by circling the most appropriate number.*

<table>
<thead>
<tr>
<th>Never</th>
<th>Not Very Often</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

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 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
<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Do you have the desire to eat when you are irritated?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Do you have a desire to eat when you have nothing to do?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Do you have a desire to eat when you are depressed or discouraged?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Do you have a desire to eat when you are feeling lonely?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>15. Do you have a desire to eat when somebody lets you down?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Do you have a desire to eat when you are cross?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>17. Do you have a desire to eat when you are approaching something unpleasant to happen?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Do you get the desire to eat when you are anxious, worried or tense?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Do you have a desire to eat when things are going against you or when things have gone wrong?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. Do you have a desire to eat when you are frightened?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. Do you have a desire to eat when you are disappointed?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Do you have a desire to eat when you are emotionally upset?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. Do you have a desire to eat when you are bored or restless?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Food Craving Questionnaire-State (Time 1)

Age:_______  Male/Female:_______

People have written a list of comments about feelings, thoughts, desires, temptations and urges related to food and eating. This list is specific for chocolate. Please, indicate how you are feeling right now by putting the number of the appropriate expression next to each sentence.

1 2 3 4 5
Strongly disagree Disagree No particular feeling on this subject Agree Strongly agree

1. I have an intense desire to eat chocolate.  1 2 3 4 5
2. I'm craving chocolate.  1 2 3 4 5
3. I have an urge for chocolate.  1 2 3 4 5
Food Craving Questionnaire-State (Time 2)

People have written a list of comments about feelings, thoughts, desires, temptations and urges related to food and eating. This list is specific for chocolate. Please, indicate how you are feeling right now by circling just one number alongside each statement.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly disagree</td>
<td>Disagree</td>
<td>No particular feeling on this subject</td>
<td>Agree</td>
<td>Strongly agree</td>
</tr>
</tbody>
</table>

1. I have an intense desire to eat chocolate.  
2. I'm craving chocolate.  
3. I have an urge for chocolate.  
4. Eating chocolate would make things seem just perfect.  
5. If I were to eat the chocolate which I am craving, I am sure my mood would improve.  
6. Eating chocolate would feel wonderful.  
7. If I ate chocolate I wouldn't feel so sluggish and lethargic.  
8. Satisfying my chocolate craving would make me feel less grouchy and irritable.  
9. I would feel more alert if I could satisfy my chocolate craving.  
10. If I had chocolate, I could not stop eating it.  
11. My desire to eat chocolate seems overpowering.  
12. I know I’m going to keep on thinking about chocolate until I actually have it.  
13. I am hungry for chocolate.  
14. If I ate chocolate right now, my stomach wouldn't feel as empty.  
15. I feel weak because of not eating chocolate.

How long ago did you eat something? ____________________________________________

How long ago did you eat chocolate? ____________________________________________
General thoughts associated with chocolate (Food Craving Questionnaire-Trait)

People have written a list of comments about feelings, thoughts, desires, temptations and urges related to food and eating. This list is specific for chocolate. Please indicate, using the words below, your feelings in general. Circle just one number alongside each statement.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Never</td>
<td>Rarely</td>
<td>Sometimes</td>
<td>Often</td>
<td>Usually</td>
<td>Always</td>
</tr>
<tr>
<td>2</td>
<td>Circle just one number</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. I eat chocolate to feel better.  
2. Sometimes, eating chocolate makes things seem just perfect.  
3. Eating chocolate makes me feel better.  
4. When I satisfy a chocolate craving I feel less depressed.  
5. Eating chocolate calms me down.  
6. I crave chocolate when I feel bored, angry, or sad.  
7. I feel less anxious after I eat chocolate  
8. When I eat chocolate I feel great.  
9. When I’m stressed out, I crave chocolate.  
10. My emotions often make me want to eat chocolate.  
11. When I eat chocolate, I feel comforted.  
12. I crave chocolate when I’m upset.  

How would you describe the experience of eating chocolate?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very unpleasant</td>
<td>Very pleasant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How much self-control do you have with chocolate?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Restraint</td>
<td>Restraint</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(“I eat chocolate whenever I want”)</td>
<td>(“I try to resist to eat chocolate”)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I often have cravings for sweets.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I often have cravings for chocolate.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How demanding did you find the computer task (Stroop task)?

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all demanding</td>
<td>Very demanding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling Scale</td>
<td>Felt Arousal Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5  Very Good</td>
<td>1  Low Arousal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2  Good</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3  Good</td>
<td>3  Fairly Good</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1  Fairly Good</td>
<td>4  Neutral</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0  Neutral</td>
<td>5  Fairly Bad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-1 Fairly Bad</td>
<td>6  High Arousal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-3 Bad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-5 Very Bad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 4. Posters for Study 2.

Are you a female (BMI >25) and a regular chocolate eater?

(ie, 100g a day or 1 chocolate bar)

If so, we need you for our study on brisk walking and concentration

Volunteers will be paid a total of £15 for completing 2 x 40-60 min laboratory sessions on the St Luke’s campus, University of Exeter.

For more information please contact
Hwajung, OH

e-mail:
mobile:
Have you given up chocolate for “Lent”??

Are you a female & a regular chocolate eater?

(ie, 100g or 1 chocolate bar a day)

If so, we need you for our study on brisk walking and concentration

Volunteers will be paid a total of £15 for completing 2 x 40-60 min laboratory sessions on the St Luke’s campus, University of Exeter.

For more information please contact Hwajung, OH

e-mail: 
mobile:
Appendix 5. A 4-day chocolate diary for study 2.

3-Day Food (chocolates) Diary

<table>
<thead>
<tr>
<th>Time</th>
<th>Day1 ( / )</th>
<th>Day2 ( / )</th>
<th>Day3 ( / )</th>
<th>Day4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How many (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mood states (FS,FAS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before eating</td>
<td>FS:</td>
<td>FAS:</td>
<td>FS:</td>
<td>FAS:</td>
</tr>
<tr>
<td>After eating</td>
<td>FS:</td>
<td>FAS:</td>
<td>FS:</td>
<td>FAS:</td>
</tr>
</tbody>
</table>

| Time | | | | |
| Where | | | | |
| How many (g) | | | | |
| Mood states (FS,FAS) | | | | |
| Before eating | FS: | FAS: | FS: | FAS: | FS: | FAS: |
| After eating | FS: | FAS: | FS: | FAS: | FS: | FAS: |

| Time | | | | |
| Where | | | | |
| How many (g) | | | | |
| Mood states (FS,FAS) | | | | |
| Before eating | FS: | FAS: | FS: | FAS: | FS: | FAS: |
| After eating | FS: | FAS: | FS: | FAS: | FS: | FAS: |

*Note: Mood states 1) Feeling Scale -5 (very bad) to (0=neutral) +5 (very good) / 2) Felt Arousal Scale 1 (Low Arousal) to 6 (High Arousal)
Appendix 6. Questionnaires for Study 2

Physical activity questionnaire

We are interested in the amount of physical activity that you personally do. Please look at the examples of different intensities of exercise below and then answer a few questions.

**Vigorous**  Squash, running, football, swimming, tennis, aerobics, cycling (if out of breath or sweaty); some occupations that involve frequent climbing, lifting, or carrying heavy loads.

**Moderate**  Football, swimming, tennis, aerobics, cycling (if not out of breath or sweaty); table tennis, golf, social dancing, exercises (if out of breath or sweaty); heavy DIY activities (for example, mixing cement), heavy gardening (e.g., digging), heavy housework (e.g., spring cleaning), walking at a brisk or fast pace, active occupations that are not vigorous..

To make this question easier we would like you to recall the physical activity you have been doing only in the past 7 days. Use the examples of different intensities in the table above.

- To help you recall if and when you exercised, first write down the day of the week for yesterday, then the day before, etc. (e.g., Monday, Sunday, Saturday).
- Then record the total number of minutes of both VIGOROUS AND MODERATE exercise you did on each day working backwards from yesterday.
- We will add up your total number of minutes of VIGOROUS AND MODERATE exercise for the past week. It is important that you fill each space in the table below even if you write ‘0 mins’.
- An example might be as follows, but everyone will be different:

<table>
<thead>
<tr>
<th>Day of week:</th>
<th>Monday</th>
<th>Sunday</th>
<th>Saturday</th>
<th>Friday</th>
<th>Thursday</th>
<th>Wednesday</th>
<th>Tuesday</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minutes of VIGOROUS</td>
<td>0 min</td>
<td>0 min</td>
<td>30 min</td>
<td>0 min</td>
<td>0 min</td>
<td>0 min</td>
<td>0 min</td>
</tr>
<tr>
<td>Minutes of MODERATE</td>
<td>10 min</td>
<td>70 min</td>
<td>10 min</td>
<td>0 min</td>
<td>0 min</td>
<td>0 min</td>
<td>20 min</td>
</tr>
</tbody>
</table>

Now your turn:

<table>
<thead>
<tr>
<th>Day of week:</th>
<th>Monday</th>
<th>Sunday</th>
<th>Saturday</th>
<th>Friday</th>
<th>Thursday</th>
<th>Wednesday</th>
<th>Tuesday</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minutes of VIGOROUS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minutes of MODERATE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- On average, how many hours have you spent SLEEPING each day in the last week? (to the nearest half-hour) _______ hours
- Please circle a number on the following scale:

<table>
<thead>
<tr>
<th>Much less</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Much more</th>
</tr>
</thead>
<tbody>
<tr>
<td>How much physical activity do you typically do in a normal week, compared with the past 7 days you have just reported.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
The Three Factor Eating Questionnaire-R18

Below are some questions about your eating habits. There are no right or wrong answers.
Please answer by circling the most appropriate answer

1. When I smell a sizzling steak or juicy piece of meat, I find it very difficult to keep from eating, even if I have just finished a meal.
   *Definitely true (4)  mostly true (3)  mostly false (2)  definitely false (1)*

2. I deliberately take small helpings as a means of controlling my weight.
   *Definitely true (4)  mostly true (3)  mostly false (2)  definitely false (1)*

3. When I feel anxious, I find myself eating.
   *Definitely true (4)  mostly true (3)  mostly false (2)  definitely false (1)*

4. Sometimes when I start eating, I just can’t seem to stop.
   *Definitely true (4)  mostly true (3)  mostly false (2)  definitely false (1)*

5. Being with someone who is eating often makes me hungry enough to eat also.
   *Definitely true (4)  mostly true (3)  mostly false (2)  definitely false (1)*

6. When I feel blue, I often overeat.
   *Definitely true (4)  mostly true (3)  mostly false (2)  definitely false (1)*

7. When I see a real delicacy, I often get so hungry that I have to eat right away.
   *Definitely true (4)  mostly true (3)  mostly false (2)  definitely false (1)*

8. I get so hungry that my stomach often seems like a bottomless pit.
   *Definitely true (4)  mostly true (3)  mostly false (2)  definitely false (1)*

Continued...
I am always hungry so it is hard for me to stop eating before I finish the food on my plate.

**Definitely true (4) mostly true (3) mostly false (2) definitely false (1)**

10. When I feel lonely, I console myself by eating.

**Definitely true (4) mostly true (3) mostly false (2) definitely false (1)**

11. I consciously hold back at meals in order not to weight gain.

**Definitely true (4) mostly true (3) mostly false (2) definitely false (1)**

12. I do not eat some foods because they make me fat.

**Definitely true (4) mostly true (3) mostly false (2) definitely false (1)**

13. I am always hungry enough to eat at any time.

**Definitely true (4) mostly true (3) mostly false (2) definitely false (1)**

14. How often do you feel hungry?

*Only at meal times (1) Sometimes between meals (2) Often between meals (3) almost always (4)*

15. How frequently do you avoid “stocking up” on tempting foods?

*Almost never (1) seldom (2) usually (3) almost always (4)*

16. How likely are you to consciously eat less than you want?

*Unlikely (1) slightly likely (2) moderately likely (3) very likely(4)*

17. Do you go on eating binges though you are not hungry?

*Never (1) rarely (2) sometimes (3) at least once a week (4)*

On a scale of 1 to 8, where 1 means no restraint in eating (eating whatever you want, whenever you want it) and 8 means total restraint (constantly limiting food intake and never “giving in”), what number would you give yourself?
The Barratt Impulsiveness Scale (BIS-11)

DIRECTIONS: People differ in the ways they act and think in different situations. This is a test to measure some of the ways in which you act and think. Read each statement and put an X on the appropriate circle on the right side of this page. Do not spend too much time on any statement. Answer quickly and honestly.

<table>
<thead>
<tr>
<th>O Occasionally</th>
<th>O Often</th>
<th>O Almost Always/Always</th>
<th>495x66</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rarely/Never</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 I plan tasks carefully.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>2 I do things without thinking.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>3 I make-up my mind quickly.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>4 I am happy-go-lucky.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>5 I don’t “pay attention.”</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>6 I have “racing” thoughts.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>7 I plan trips well ahead of time.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>8 I am self controlled.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>9 I concentrate easily.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>10 I save regularly.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>11 I “squirm” at plays or lectures.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>12 I am a careful thinker.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>13 I plan for job security.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>14 I say things without thinking.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>15 I like to think about complex problems.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>16 I change jobs.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>17 I act “on impulse.”</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>18 I get easily bored when solving thought problems.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>19 I act on the spur of the moment.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>20 I am a steady thinker.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>21 I change residences.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>22 I buy things on impulse.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>23 I can only think about one thing at a time.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>24 I change hobbies.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>25 I spend or charge more than I earn.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>26 I often have extraneous thoughts when thinking.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>27 I am more interested in the present than the future.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>28 I am restless at the theater or lectures.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>29 I like puzzles.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>30 I am future oriented.</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Q1</td>
<td>I find myself thinking about food even when I’m not physically hungry</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------------------</td>
<td>----------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Q2</td>
<td>I get more pleasure from eating than I do from almost anything else</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q3</td>
<td>If I see or smell a food I like, I get a powerful urge to have some</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q4</td>
<td>When I’m around a fattening food I love, it’s hard to stop myself from at least tasting it</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q5</td>
<td>It’s scary to think of the power that food has over me</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q6</td>
<td>When I know a delicious food is available, I can’t help myself from thinking about having some</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q7</td>
<td>I love the taste of certain foods so much that I can’t avoid eating them even if they’re bad for me</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q8</td>
<td>Just before I taste a favorite food, I feel intense anticipation</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q9</td>
<td>When I eat delicious food I focus a lot on how good it tastes</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q10</td>
<td>Sometimes, when I’m doing everyday activities, I get an urge to eat “out of the blue” (for no apparent reason)</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q11</td>
<td>I think I enjoy eating a lot more than most other people</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q12</td>
<td>Hearing someone describe a great meal makes me really want to have something to eat</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q13</td>
<td>It seems like I have food on my mind a lot</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q14</td>
<td>It’s very important to me that the foods I eat are as delicious as possible</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
<tr>
<td>Q15</td>
<td>Before I eat a favourite food my mouth tends to flood with saliva</td>
<td>I don’t agree at all</td>
<td>I agree a little</td>
</tr>
</tbody>
</table>

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The Food Chocolate-Craving Questionnaire-Trait

Age:_________ Male/Female:____________

People have written a list of comments about feelings, thoughts, desires, temptations and urges related to food and eating. This list is specific for chocolate. Please, indicate in the space next to each sentence the most appropriate word to describe your feeling in general.

<table>
<thead>
<tr>
<th>Never (1)</th>
<th>Rarely (2)</th>
<th>Sometimes (3)</th>
<th>Often (4)</th>
<th>Usually (5)</th>
<th>Always (6)</th>
</tr>
</thead>
</table>

1. ___ Being with someone who is eating often makes me hungry for chocolate.
2. ___ When I crave chocolate, I know I won’t be able to stop eating once I start.
3. ___ If I eat chocolate, I often lose control and eat too much.
4. ___ I hate it when I give into chocolate cravings.
5. ___ Chocolate cravings invariably make me think of ways to get chocolate.
6. ___ I feel like I have chocolate on my mind all the time.
7. ___ I often feel guilty for craving chocolate.
8. ___ I find myself preoccupied with chocolate.
9. ___ I eat chocolate to feel better.
10. ___ Sometimes, eating chocolate makes things seem just perfect.
11. ___ Thinking about chocolate makes my mouth water.
12. ___ I crave chocolate when my stomach is empty.
13. ___ I feel as if my body asks me for chocolate.
14. ___ I get so hungry for chocolate that my stomach seems like a bottomless pit.
15. ___ Eating chocolate makes me feel better.
16. ___ When I satisfy a chocolate craving I feel less depressed.
17. ___ When I eat chocolate I feel guilty about myself.
18. ___ Whenever I have chocolate cravings, I find myself making plans to eat.
19. ___ Eating chocolate calms me down.
20. ___ I crave chocolate when I feel bored, angry, or sad.
21. ___ I feel less anxious after I eat chocolate.
22. ___ If I get chocolate I cannot stop myself from eating it.
23. ___ When I crave chocolate, I usually try to eat it as soon as I can.
24. ___ When I eat chocolate I feel great.
25. ___ I have no will power to resist my chocolate craving.
26. ___ Once I start eating chocolate, I have trouble stopping.
27. ___ I can’t stop thinking about eating chocolate no matter how hard I try.
28. ___ I spend a lot of time thinking about chocolate I will eat next.
29. ___ If I give in to a chocolate craving, all control is lost.
30. ___ When I’m stressed out, I crave chocolate.
31. ___ I daydream about chocolate.
32. ___ Whenever I have a chocolate craving, I keep on thinking about eating until I actually eat the food.
33. ___ If I am craving chocolate, thoughts of eating it consume me.
34. ___ My emotions often make me want to eat chocolate.
35. ___ Whenever I go to a buffet I end up eating more chocolate than what I needed.
36. ___ It is hard for me to resist the temptation to eat chocolate that is in my reach.
37. ___ When I am with someone who is overeating chocolate, I usually overeat too.
38. ___ When I eat chocolate, I feel comforted.
39. ___ I crave chocolate when I’m upset.

How much do you like chocolate?

Very Unpleasant 1 2 3 4 5 6 7 8 9 Very Pleasant

How much self-control do you have with chocolate?

No Restraint 1 2 3 4 5 6 7 8 9 Restraint
(“I eat chocolate whenever (“I try to resist to eat I want”) chocolate”)
Chocolate Craving Q

Please place a mark on the line to indicate the intensity of your current craving for chocolate.

1. How strong is your desire to eat chocolate now?

Not at all  ___________________________ Extremely

2. How much do you crave chocolate at this very moment?

No craving at all  ___________________________ Extremely craving

3. How hungry are you at the moment?

Not hungry at all  ___________________________ Extremely hungry

4. I have an intense desire to eat a snack. (Circle one number)

<table>
<thead>
<tr>
<th>Feeling Scale</th>
<th>Felt Arousal Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Very Good</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>-1</td>
<td>6</td>
</tr>
<tr>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>-3</td>
<td>7</td>
</tr>
<tr>
<td>-4</td>
<td></td>
</tr>
<tr>
<td>-5</td>
<td>8</td>
</tr>
</tbody>
</table>

5. I’m craving a snack. (Circle one number)

<table>
<thead>
<tr>
<th>Feeling Scale</th>
<th>Felt Arousal Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Very Good</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
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<tr>
<td>2</td>
<td>3</td>
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<tr>
<td>1</td>
<td>4</td>
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<tr>
<td>0</td>
<td>5</td>
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<tr>
<td>-1</td>
<td>6</td>
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<tr>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>-3</td>
<td>7</td>
</tr>
<tr>
<td>-4</td>
<td></td>
</tr>
<tr>
<td>-5</td>
<td>8</td>
</tr>
</tbody>
</table>

6. I have an urge for snacking. (Circle one number)

<table>
<thead>
<tr>
<th>Feeling Scale</th>
<th>Felt Arousal Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Very Good</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
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<tr>
<td>2</td>
<td>3</td>
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<tr>
<td>1</td>
<td>4</td>
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<tr>
<td>0</td>
<td>5</td>
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<tr>
<td>-1</td>
<td>6</td>
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<tr>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>-3</td>
<td>7</td>
</tr>
<tr>
<td>-4</td>
<td></td>
</tr>
<tr>
<td>-5</td>
<td>8</td>
</tr>
</tbody>
</table>
Appendix 7. A pair of food and neutral image for Study 2.

1) Centre cross

![Centre cross image]

2) A pair of food and neutral image

![A pair of food and neutral image]

3) A dot

![A dot image]
# Appendix 8. Interview data for normal weight, overweight, and Lenters in Study 2

## Interview-normal weight

| ID:1 | 1. Where and when did you last eat chocolate? Boston Tea party...I had a chocolate brownie with a cup of tea |
|      | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. In town, I was tiered...a bit hung over (laughs) I didn’t feel great. I was having a chat in Boston Tea party with my friend and a cup of tea. |
|      | 3. Can you say why you wanted/needed chocolate at that particular moment? Chocolate always helps me with my hangover. Feels like it gives me a boost in energy and makes me feel better |

| ID:2 | 1. Where and when did you last eat chocolate? Saturday at work. It was long...it was a horrible day |
|      | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. I felt tired...I was at work |
|      | 3. Can you say why you wanted/needed chocolate at that particular moment? To...lift my energy |

| ID:3 | 1. Where and when did you last eat chocolate? On Tuesday afternoon sat on the train going home |
|      | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. I was tired and really fancied some chocolate, rrrrr I was quite hungry and needed some sugar because I was tired. I was just sitting quite comfortably. |
|      | 3. Can you say why you wanted/needed chocolate at that particular moment? Uurrrmm I wanted chocolate for comfort because I was tierd and I needed the sugar rush |

| ID:4 | 1. Where and when did you last eat chocolate? After a hockey match on wednesday |
|      | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. I felt tired from the game I was walking back from main site |
|      | 3. Can you say why you wanted/needed chocolate at that particular moment? I was actually pretty hungry...and drained from the game so needed some chocolate |

| ID:5 | 1. Where and when did you last eat chocolate? Dinner in cloisters restaurant....at about 5.30 two days ago |
|      | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. Hungry.....Well I wasn’t hungry it was after my main meal...I was in the dinner hall.....eating and talking |
|      | 3. Can you say why you wanted/needed chocolate at that particular moment? It was there and I was hungry (laughs) |

| ID:6 | 1. Where and when did you last eat chocolate? The day before last...I had some chocolate at work |
|      | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. At work...feeling lousy (laughs) working on the computer |
|      | 3. Can you say why you wanted/needed chocolate at that particular moment? Part of the mid morning energy crash. Mentally just because...feeling low |

| ID:7 | 1. Where and when did you last eat chocolate? Not yesterday but the day before in the evening at the train station. |
|      | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. I was at the train station....I had a long wait |
|      | 3. Can you say why you wanted/needed chocolate at that particular moment? Uurrrmm I wasn’t really hungry I just wanted some to eat |

| ID:8 | 1. Where and when did you last eat chocolate? Uurrrmm in the library on Saturday afternoon |
|      | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. Urrrm I couldn’t really concentrate.....I was writing an
3. Can you say why you wanted/needed chocolate at that particular moment? urrrmm to have energy and to cheer me up a bit |(laughs)

ID:9  
1. Where and when did you last eat chocolate? Wednesday 5.30 at my house
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. Just had dinner...didn’t feel satisfied. My partner went to the shop and bought several different types
3. Can you say why you wanted/needed chocolate at that particular moment? Just had dinner but didn’t feel satisfied. Chocolate in my head started a trigger and it was all I wanted

ID:10  
1. Where and when did you last eat chocolate? About 11.15 two days ago in the computer room
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. I was doing boring university work in the computer room...I need needed a boost to lift my mood
3. Can you say why you wanted/needed chocolate at that particular moment? Just to give me a little lift I suppose

ID:11  
1. Where and when did you last eat chocolate? It was the evening before last.....
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. urrrmmm I always feel I have to have some chocolate after tea. I felt happy when I ate it.
3. Can you say why you wanted/needed chocolate at that particular moment? Yeah cuz I always feel like I want chocolate after a meal and I hadn’t had that much that day either....so I needed some for that reason

ID:12  
1. Where and when did you last eat chocolate? two days ago...it was eerrr at my work
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. I really wanted to have chocolate...and I was hungry...I was playing with the jewlerry
3. Can you say why you wanted/needed chocolate at that particular moment? I get really urgey for chocolate...I don’t know why

ID:13  
1. Where and when did you last eat chocolate? Uurrrmmm Friday afternoon
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. Id been to firehouse...urrmmm I felt pretty average......my boyfriend was down and he had a mars bar and was like do you want some? SO I couldn’t turn it down.
3. Can you say why you wanted/needed chocolate at that particular moment? It was offered...I couldn’t not take it

ID:14  
1. Where and when did you last eat chocolate? uurmm at home in the evening after dinner
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. I can’t remember what I had...I probably felt like I wanted to eat some chocolate (where were you) I was at home (and what were you doing) I was watching television and I had some chocolate with my ice cream actually
3. Can you say why you wanted/needed chocolate at that particular moment? Otherwise the vanilla ice cream would have been lame

ID:15  
1. Where and when did you last eat chocolate? uurrr the night before last....for dinner
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. Uurrrmmm I felt hungry and dissatisfied...I was watching television because my dinner didn’t fill me up and I was craving sugar...like chocolate

ID:16  
1. Where and when did you last eat chocolate? I ate chocolate I think about two days ago on sunday
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. I cant remember what I had...I probably felt like I wanted to eat some chocolate (where were you) I was at home (and what were you doing) I was watching television...and I had some chocolate with my ice cream actually
3. Can you say why you wanted/needed chocolate at that particular moment? Otherwise the vanilla ice cream would have been lame

ID:17  
1. Where and when did you last eat chocolate? Saturday in my room at about 3 oclock
| ID:18 | 1. Where and when did you last eat chocolate? At home on Sunday  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. uurrmm hungry (and what were u doing) uurrmm reading a book  
3. Can you say why you wanted/needed chocolate at that particular moment? cuz my belly hurt |
| ID:19 | 1. Where and when did you last eat chocolate? Sunday....i think I had a coco drink on Sunday night at my house  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. I was just thinking to myself whilst sitting quietly I felt fine. I was at home!  
3. Can you say why you wanted/needed chocolate at that particular moment? I did need it I wanted it (laughs) |
| ID:20 | 1. Where and when did you last eat chocolate? Urrrrmm At home two days ago  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing. I felt normal realy...I had a bit of a craving....I was watching tv  
3. Can you say why you wanted/needed chocolate at that particular moment? I didn’t need it....I just fancied it |

### Interview-overweight

| ID:1 | 1. Where and when did you last eat chocolate?  
I ate chocolate in my office before lunch time.  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
I was on the phone and was upset about something. Unconsciously, I opened snack box and I ate some chocolates until I finish the chatting.  
3. Can you say why you wanted/needed chocolate at that particular moment?  
I needed some sweets to release my stress. |
| ID:2 | 1. Where and when did you last eat chocolate?  
I ate the last chocolate a cafeteria in University. Normally, I have some chocolate during break-time and it is around 11am or 12pm.  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
After proper meal, I want to eat chocolate as a dessert.  
3. Can you say why you wanted/needed chocolate at that particular moment?  
Just craving for chocolate or chocolate related products after lunch with a cup of tea. Normally after heavy meal, I want to eat chocolate. Also, after eating salty food, I think that I need to eat some chocolate as compensatory. I ate salty food and then I need sweet food to keep balance. |
| ID:3 | 1. Where and when did you last eat chocolate?  
With friends in a hall on Saturday evening  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
We had just one quiz and chocolate was given to all the people on the quiz. Our team had some chocolates and we ate it. It was happy thing. The one I ate was my preference. I am fussy about the chocolate.  
3. Can you say why you wanted/needed chocolate at that particular moment?  
I didn’t need but I wanted. It was nice thing to have. Everyone else was there and also |
having it. It’s also because feels nice in the mouth.

| ID:4 | 1. **Where and when did you last eat chocolate?**  
At late night, I ate dark almond chocolates at home. |
| | 2. **I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.**  
I was on the computer and was thinking about going to bed. I’d eaten dinner and just thought of some chocolate pop in my mind. I felt hungry even though it was after 1 and half hour after dinner. |
| | 3. **Can you say why you wanted/needed chocolate at that particular moment?**  
Various reasons. I don’t like going to bed. I am not morning person. Maybe it was to cheer me up before going to bed. Do eat a lot the resting of night more than during day. I was kinds of bored and felt hungry after thinking about chocolate. |

| ID:5 | 1. **Where and when did you last eat chocolate?**  
It was in kitchen at 3pm on Friday. |
| | 2. **I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.**  
In the kitchen with my friends. I was quite happy because it was my friend’s birthday. We had some chocolate cakes and I felt good after. |
| | 3. **Can you say why you wanted/needed chocolate at that particular moment?**  
It was there in front of me, so I just ate as it looked nice and I wanted to eat. |

| ID:6 | 1. **Where and when did you last eat chocolate?**  
The day before yesterday on the bus I ate some chocolate |
| | 2. **I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.**  
I tried not to eat chocolate but suddenly, my daughter said “I don’t want to eat anymore” and gave me the chocolate pack. I even didn’t think about eating and I was not hungry. I was not craving for chocolate. Just gave me the pack and I ate it. It was completely thoughtless. I had nothing in my mind. I just ate eat. When I empty the pack, in my mind, “Oh, my God!”. |
| | 3. **Can you say why you wanted/needed chocolate at that particular moment?**  
I don’t know why, but I thought it was appropriate to eat chocolate. On that day I went to cinema and walked around. I felt it is appropriate situation to eat chocolate. Actually, I don’t think when I eat. |

| ID:7 | 1. **Where and when did you last eat chocolate?**  
I ate chocolate at 9am before starting work |
| | 2. **I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.**  
I was feeling hungry and needed energy, so I took chocolates because it’s fast food. At that time I was sitting at work. |
| | 3. **Can you say why you wanted/needed chocolate at that particular moment?**  
It’s convenient and quick. I really enjoyed it. I am sure that chocolate makes feel better. |

| ID:8 | 1. **Where and when did you last eat chocolate?**  
It was at home at 1pm. |
| | 2. **I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.**  
I was at home and felt a bit hungry. My mood was find but also I felt that I need some energy. |
| | 3. **Can you say why you wanted/needed chocolate at that particular moment?**  
No energy and I just want to pick me up. So, I had some chocolates. |

| ID:9 | 1. **Where and when did you last eat chocolate?**  
It was at home and at night. |
| | 2. **I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.**  
I was sitting and watching TV. My feeling was OK. |
| | 3. **Can you say why you wanted/needed chocolate at that particular moment?**  
I don’t know why I wanted the chocolate. I was nothing to do and just need something to do. It was there and I ate. |
1. Where and when did you last eat chocolate?
   It was last night (around 8pm) at home.

2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.
   I was watching TV and I felt a bit cold. I don’t know why, but I felt eating some chocolate will make me warmer.

3. Can you say why you wanted/needed chocolate at that particular moment?
   I didn’t do anything in front of TV and felt a bit hungry. I felt that chocolates such a high caloric food will make me feel full. Another reason I ate chocolate is because of my friends. I couldn’t ignore the chocolates when I saw my friend’s eating chocolate.

---

1. Where and when did you last eat chocolate?
   It was Saturday night and it was at home.

2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.
   I was watching the TV, and I thought I could have a piece of chocolate, my little starch downstairs. I was just relax and was kinds of normal.

3. Can you say why you wanted/needed chocolate at that particular moment?
   It was because I was relax and wasn’t busy, I was just fancy of the pieces.

---

1. Where and when did you last eat chocolate?
   Friday night at half pass 6 evening.

2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.
   I was hungry and it was just before the evening meal. I needed something sort of filling a gap.

3. Can you say why you wanted/needed chocolate at that particular moment?
   I think I was a bit hungry and needed something sweets.

---

1. Where and when did you last eat chocolate?
   It was Saturday morning at home.

2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.
   It was very early morning before work and I was a bit moody. I am very emotional about chocolate. I just wanted to eat some chocolate to release my emotional trigger.

3. Can you say why you wanted/needed chocolate at that particular moment?
   It was long day for working. I wanted nice chocolate taste as I know chocolate gives me good mood like a treatment. After eating chocolate, I normally feel good.

---

1. Where and when did you last eat chocolate?
   It was Wednesday evening at work.

2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.
   I was watching TV and I felt I need some chocolate. I was bored at that moment.

3. Can you say why you wanted/needed chocolate at that particular moment?
   I don’t know why but I really fancy to the chocolate.

---

1. Where and when did you last eat chocolate?
   It was the day before yesterday at home in the evening.

2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.
   I was watching TV after having dinner. I was just bored and wanted to eat some snacks.

3. Can you say why you wanted/needed chocolate at that particular moment?
| ID:17 | 1. Where and when did you last eat chocolate?  
It was Friday morning in my room  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
I was watching TV. I was relaxing while watching a TV programme.  
3. Can you say why you wanted/needed chocolate at that particular moment?  
Normally I eat something while watching TV, so I needed something to eat at the moment, although it was just after meal. |
| ID:18 | 1. Where and when did you last eat chocolate?  
I was at home. It was night time  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
Just I was bored and brought some chocolate beside me.  
3. Can you say why you wanted/needed chocolate at that particular moment?  
I don’t know. Just wanted to eat something sweet and it was there. |
| ID:19 | 1. Where and when did you last eat chocolate?  
At home and it was after dinner.  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
I was bored and watched TV. I went to kitchen to drink something and I saw the chocolate. I grabbed 4 bars of chocolate.  
3. Can you say why you wanted/needed chocolate at that particular moment?  
I was bored and I know the taste of chocolate. So, I ate them all as usual. |
| ID:20 | 1. Where and when did you last eat chocolate?  
Saturday afternoon in a cafe  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
I felt guilty. I have a breakfast and had the chocolate after that. I was in town with my Son.  
3. Can you say why you wanted/needed chocolate at that particular moment?  
I saw the chocolate and I was fancy them. |
| ID:21 | 1. Where and when did you last eat chocolate?  
In the street on my back home  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
I thought I was been very sneaky because I didn’t eat chocolate at that day. I went to shop. Feeling I’m going to buy myself small bar of chocolates. Nobody knows and I can eat now.  
3. Can you say why you wanted/needed chocolate at that particular moment?  
I didn’t need it but I wanted because it was there and thought about going to shop and taste of it. |

**Interview-Lent group**

| ID:1 | 1. Where and when did you last eat chocolate?  
About midnight (or a few mins before) on the Tuesday night (8th March) before Lent started on the Wednesday. At home.  
2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
I made a massive chocolate cake and took it to my guitar evening class on the Tuesday. I shared it around when we had a break at 8pm. I had some then and after the class (9pm) and just carried on eating it until it was gone and the day was over. I really really wanted to eat it during the first half of the class but knew I couldn’t, but once it was started then I just carried on eating. By the way, this was a chocolate flavoured cake with extra pieces of chocolate in it and chocolate fudge icing on top decorated with grated chocolate. |
| ID:2 | Where and when did you last eat chocolate?  
On Tuesday, before starting Lent, on the way out shop I ate a pack of chocolate (buttons) |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.</td>
</tr>
<tr>
<td></td>
<td>I had had really bad day on placements. After eating some chocolate, I felt better in a few minutes. Before eating it, I was on my way at home and was straight away to the shop.</td>
</tr>
<tr>
<td></td>
<td>Can you say why you wanted/needed chocolate at that particular moment?</td>
</tr>
<tr>
<td></td>
<td>I was feeling really upset and I knew that if I have some chocolate my feeling will be better for a bit.</td>
</tr>
<tr>
<td>ID:3</td>
<td>Where and when did you last eat chocolate?</td>
</tr>
<tr>
<td></td>
<td>It was before starting Lent and I was in the Kitchen.</td>
</tr>
<tr>
<td></td>
<td>I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.</td>
</tr>
<tr>
<td></td>
<td>After dinner I was quite full but I felt that I need some sweets.</td>
</tr>
<tr>
<td></td>
<td>Can you say why you wanted/needed chocolate at that particular moment?</td>
</tr>
<tr>
<td></td>
<td>Probably, I didn’t need it but I just wanted to eat some chocolate</td>
</tr>
<tr>
<td>ID:4</td>
<td>Where and when did you last eat chocolate?</td>
</tr>
<tr>
<td></td>
<td>It was Monday evening in my room before doing Lent.</td>
</tr>
<tr>
<td></td>
<td>I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.</td>
</tr>
<tr>
<td></td>
<td>I just had dinner and naturally eat sweets after dinner. I was in my room doing lots of work on computer.</td>
</tr>
<tr>
<td></td>
<td>Can you say why you wanted/needed chocolate at that particular moment?</td>
</tr>
<tr>
<td></td>
<td>I think it’s just because I need to eat something sweet after meal such as savory as a habit. And it was just there so I ate some chocolates.</td>
</tr>
<tr>
<td>ID:5</td>
<td>Where and when did you last eat chocolate?</td>
</tr>
<tr>
<td></td>
<td>In the morning, at work.</td>
</tr>
<tr>
<td></td>
<td>I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.</td>
</tr>
<tr>
<td></td>
<td>I was tired and hungry before lunch. I was sitting at the desk and doing some paper work. I wanted me to wake up, so I ate some chocolate.</td>
</tr>
<tr>
<td></td>
<td>Can you say why you wanted/needed chocolate at that particular moment?</td>
</tr>
<tr>
<td></td>
<td>I was hungry and bored about my work, so eating chocolate was a nice treatment.</td>
</tr>
<tr>
<td>ID:6</td>
<td>Where and when did you last eat chocolate?</td>
</tr>
<tr>
<td></td>
<td>I cannot remember the date, but It was coffee shop in the afternoon.</td>
</tr>
<tr>
<td></td>
<td>I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.</td>
</tr>
<tr>
<td></td>
<td>I was in the library and having a coffee break with friends. I was probably quite stressed and bored as well.</td>
</tr>
<tr>
<td></td>
<td>Can you say why you wanted/needed chocolate at that particular moment?</td>
</tr>
<tr>
<td></td>
<td>I was bored and to make me feel better I ate it.</td>
</tr>
<tr>
<td>ID:7</td>
<td>Where and when did you last eat chocolate?</td>
</tr>
<tr>
<td></td>
<td>It was just the day before starting Lent, in a cinema.</td>
</tr>
<tr>
<td></td>
<td>I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.</td>
</tr>
<tr>
<td></td>
<td>Well, I went to the cinema with friends, and I know it would be the last time I was going to have chocolate for the entire of lent, so I ate two different types of chocolate and felt good.</td>
</tr>
<tr>
<td></td>
<td>Can you say why you wanted/needed chocolate at that particular moment?</td>
</tr>
<tr>
<td></td>
<td>I always need to have a snack when I go the cinema, and as it was the day before lent I wanted to eat as much as I could as I knew it would be the last time for a while.</td>
</tr>
</tbody>
</table>
| ID: 8 | 1. Where and when did you last eat chocolate?  
|       | It was my friend's house on Pancake day.  
|       | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
|       | I had a gathering with my friend, so I was relaxed and happy. At her house, I was watching TV and had some chocolate.  
|       | 3. Can you say why you wanted/needed chocolate at that particular moment?  
|       | I didn’t need chocolate, but many friends were there and everyone ate chocolate. And it was the last day before starting Lent.  |
| ID: 9 | 1. Where and when did you last eat chocolate?  
|       | It was a restaurant at night.  
|       | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
|       | I was with my friends and we wanted to order some chocolate.  
|       | 3. Can you say why you wanted/needed chocolate at that particular moment?  
|       | I don’t know, but just it was a nice option.  |
| ID: 10 | 1. Where and when did you last eat chocolate?  
|        | It was on Pancake day about 7pm.  
|        | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
|        | My whole flat-mates had pancakes with some desserts and chocolates. I was happy with my friends.  
|        | 3. Can you say why you wanted/needed chocolate at that particular moment?  
|        | It’s because it was in front of me.  |
| ID: 11 | 1. Where and when did you last eat chocolate?  
|        | At home in the evening.  
|        | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
|        | I was studying and was too bored from work.  
|        | 3. Can you say why you wanted/needed chocolate at that particular moment?  
|        | I was bored from study and needed some chocolate to wake me up.  |
| ID: 12 | 1. Where and when did you last eat chocolate?  
|        | It was pan-cake day in my friend’s house  
|        | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
|        | I was happy and relax. It was social event.  
|        | 3. Can you say why you wanted/needed chocolate at that particular moment?  
|        | I didn’t need the chocolate but just wanted to enjoy the last chocolate.  |
| ID: 13 | 1. Where and when did you last eat chocolate?  
|        | It was a month ago in my boyfriend’s mother’s house.  
|        | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
|        | We’d just finished lunch and thought that we need something for deserts.  
|        | 3. Can you say why you wanted/needed chocolate at that particular moment?  
|        | There’s no reason. Chocolate was there and I like chocolate. So, I just ate some chocolates after meal.  |
| ID: 14 | 1. Where and when did you last eat chocolate?  
|        | It was before Lent in my room. It was midnight.  
|        | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.  
|        | I bought 5 bars of chocolate the day, and I ate them all in front of TV. I was a bit nervous that I have to giving up chocolate, although I did it before. So, I enjoyed the last day.  
|        | 3. Can you say why you wanted/needed chocolate at that particular moment?  
|        | Because I knew that I cannot have it for few weeks.  |
| ID: 15 | 1. Where and when did you last eat chocolate?  
|        | It was at home after put children to bed. About 8pm in the evening.  
|        | 2. I am interested in your thoughts prior to eating, concerning how you felt, where you
| ID:16 | 1. **Where and when did you last eat chocolate?**  
   It was at home in the evening.  
2. **I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.**  
   After work I was tired and want to be relaxed. Before I go to bed, I normally eat chocolates as a habit.  
3. **Can you say why you wanted/needed chocolate at that particular moment?**  
   Chocolate makes me feel better. |

| ID:17 | 1. **Where and when did you last eat chocolate?**  
   At work in the afternoon  
2. **I am interested in your thoughts prior to eating, concerning how you felt, where you were, and what you were doing.**  
   It was after lunch mid-afternoon and I was just working on the computer. And I started craving for chocolate with a cup of tea.  
3. **Can you say why you wanted/needed chocolate at that particular moment?**  
   I think I needed sugar booster some sort to give me lift let through the afternoon and on the computer’s very boring. |
Appendix 9. CVD risk factor assessment

**CVD Risk Factor Assessment for Exercise Testing and Prescription**

To be used following completion of PAR-Q

**Study:** __________________________  **Subject ID:** ________  **Date:** __________

**Enter a 1 for yes or 0 for no**

- **Family History** (1)
  - Current smoker or smoker in the last 6 months
  - Systolic BP ≥ 140 or Diastolic BP ≥ 90 mm Hg
  - (If systolic BP > 200 or Diastolic > 110 **then do not test**)
  - BMI ≥ 30, or waist girth > 102 cm in men or > 88 cm in women (2)
  - Sedentary (3)
  - Age > 45 if male or >55 if female

Sum of positive risk factors (A1)

If sum of above positive risk factors, A1, is zero then OK to test without further assessment.

If sum is **1 or more** then the following blood measurements **must** be made and assessed:

- **Total cholesterol > 5.2 mmol·l⁻¹**
- **Fasting blood glucose ≥ 6.1 mmol·l⁻¹** or non-fasting blood glucose > 11.1 mmol·l⁻¹ (4)
- Sum of positive risk factors (A2)

**Enter a 1 for yes or 0 for no**

- **HDL-C > 1.6 mmol·l⁻¹**
- Sum of negative risk factors (B)

**Total risk factor score [(A1 + A2) – B]**

(1) Family History refers to heart attack in father or brother before age 55 or mother or sister before age 65.

(2) Waist girth should be measured with an inelastic tape in a horizontal plane at the narrowest part of the torso.

(3) Sedentary refers to individuals not engaged in a regular exercise programme or those not undertaking 30 minutes of moderate physical activity on three or more days of the week.

(4) Impaired fasting glucose should be confirmed by measurements on at least two separate occasions.

*Version: September 2009*
PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
2. Do you feel pain in your chest when you do physical activity?
3. In the past month, have you had chest pain when you were not doing physical activity?
4. Do you lose your balance because of dizziness or do you ever lose consciousness?
5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
7. Do you know of any other reason why you should not do physical activity?

If you answered YES to one or more questions
Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.
- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

If you answered NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:
- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:
- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME

SIGNATURE

DATE

SIGNATURE OF PARENT
or GUARDIAN (for participants under the age of majority)

WITNESS

261
Appendix 10. Eye-tracking images for Study 3.

1) Calibration

2) Example of video clips used for eye-tracker

Snacking
Smoking
Appendix 11. Questionnaires for Study 3.

The Barratt Impulsiveness Scale

For each statement, circle a number to the right to indicate how well it describes you.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Often</th>
<th>Almost always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I plan tasks carefully/</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2. I do things without thinking.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3. I don’t “pay attention.”</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4. I concentrate easily</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5. I save money on a regular basis</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6. I squirm at plays or lectures.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7. I am a careful thinker.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8. I plan for job security.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9. I say things without thinking.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10. I act “on impulse.”</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11. I get easily bored when solving thought problems.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>12. I act on the spur of the moment.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>13. I buy things on impulse.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>14. I am restless at lectures or talks.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>15. I plan for the future.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
### Mood and Physical Symptoms Scale (MPSS)

Please show for each of the items below how you feel **now**

(Circle one number for each item)

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Slightly</th>
<th>Somewhat</th>
<th>Very</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depressed</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Irritable</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Restless</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Hungry</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Poor concentration</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

1. How strong are your smoking urges **now**? (Circle one number)

<table>
<thead>
<tr>
<th>No urges</th>
<th>Slight</th>
<th>Moderate</th>
<th>Strong</th>
<th>Very strong</th>
<th>Extremely strong</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

2. I have an intense desire to eat a snack. (Circle one number)

<table>
<thead>
<tr>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>No particular feeling on this subject</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

3. I’m craving a snack. (Circle one number)

<table>
<thead>
<tr>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>No particular feeling on this subject</th>
<th>Agree</th>
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4. I have an urge for snacking. (Circle one number)

<table>
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<tr>
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INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of heir everyday lives. This is part of a large study being conducted in many countries around the world. Your answers will help us to understand how active we are compared with people in other countries. The questions are about the time you spent being physically active in the last 7 days. They include questions about activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport. Your answers are important.

Please answer each question even if you do not consider yourself to be an active person.

THANK YOU FOR PARTICIPATING.

In answering the following questions,
- vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder that normal.
- moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder that normal.

This is the final SHORT LAST 7 DAYS SELF-ADMINISTERED version of IPAQ from the 2000/01 Reliability and Validity Study. Completed May 2001.

1. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling? (Think about only those physical activities that you did for at least 10 minutes at a time.)
   _______ days per week  Or  none
   How much time did you typically spend on each of those days doing vigorous physical activities?
   _______ hours _______ minutes per day

2. Again, think only about those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.
   _______ days per week  Or  none
   How much time did you typically spend on each of those days doing moderate physical activities?
   _______ hours _______ minutes per day

3. During the last 7 days, on how many days did you walk for at least 10 minutes at a time? (This includes walking at work and at home, walking to travel from place to place, and any other walking that you did solely for recreation, sport, exercise or leisure.)
   _______ days per week  Or  none
   How much time did you typically spend walking at a brisk pace on each of those days?
   _______ hours _______ minutes per day

The last question is about the time you spent sitting on weekdays while at work, at home, while doing course work and during leisure time. This includes time spent sitting at a desk, visiting friends, reading travelling on a bus or sitting or lying down to watch television.

4. During the last 7 days, how much time in total did you usually spend sitting on a week day?
   ____ hours _____ minutes per weekday

This is the end of questionnaire, thank you for participating.
**Eating behaviours**
(Restraint Scale and TFEQ-R18)

*Below are some questions about your eating habits. There are no right or wrong answers. Please answer by circling the most appropriate answer.*

1. How often are you dieting?

   - Never
   - Rarely
   - Sometimes
   - Usually
   - Always

2. What is the maximum amount of weight (in pounds) you have ever lost within one month?

   - 0 - 4 (1.8kg)
   - 5 - 9 (4.1kg)
   - 10 - 14 (6.4kg)
   - 15 - 19 (8.6kg)
   - 20+ (9.1kg)

3. What is your maximum weight gain within a week?

   - 0 - 1 (0.5kg)
   - 1.1 - 2 (1kg)
   - 2.1 - 3 (1.4kg)
   - 3.1 - 5 (2.3kg)
   - 5.1+

4. In a typical week, how much does your weight fluctuate?

   - 0 – 1
   - 1.1 - 2
   - 2.1 - 3
   - 3.1 - 5
   - 5.1+

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

   - Not at all
   - Slightly
   - Moderately
   - Extremely

6. Do you eat sensible in front of others and splurge alone?

   - Never
   - Rarely
   - Often
   - Always

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

   - Never
   - Rarely
   - Often
   - Always

8. Do you have feelings of guilt after overeating?

   - Never
   - Rarely
   - Often
   - Always

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

   - Not at all
   - Slightly
   - Moderately
   - Extremely

10. How many pounds over your desired weight were you at your maximum weight?

    - 0 – 1
    - 1 (0.5kg) -5 (2.3kg)
    - 6 (2.7kg) -10 (4.5kg)
    - 11 (5kg) – 20 (9.1kg)
    - 21+ (9.5kg)
11. When I smell a sizzling steak or juicy piece of meat, I find it very difficult to keep from eating, even if I have just finished a meal.

(1) Definitely false   (2) Mostly false   (3) Mostly true   (4) Definitely true

12. When I feel anxious, I find myself eating.

(1) Definitely false   (2) Mostly false   (3) Mostly true   (4) Definitely true

13. Sometimes when I start eating, I just can’t seem to stop.

(1) Definitely false   (2) Mostly false   (3) Mostly true   (4) Definitely true

14. Being with someone who is eating often makes me hungry enough to eat also.

(1) Definitely false   (2) Mostly false   (3) Mostly true   (4) Definitely true

15. When I feel blue, I often overeat.

(1) Definitely false   (2) Mostly false   (3) Mostly true   (4) Definitely true

16. When I see a real delicacy, I often get so hungry that I have to eat right away.

(1) Definitely false   (2) Mostly false   (3) Mostly true   (4) Definitely true

17. I get so hungry that my stomach often seems like a bottomless pit.

(1) Definitely false   (2) Mostly false   (3) Mostly true   (4) Definitely true

18. I am always hungry so it is hard for me to stop eating before I finish the food on my plate.

(1) Definitely false   (2) Mostly false   (3) Mostly true   (4) Definitely true

19. When I feel lonely, I console myself by eating.

(1) Definitely false   (2) Mostly false   (3) Mostly true   (4) Definitely true

20. I am always hungry enough to eat at any time.

(1) Definitely false   (2) Mostly false   (3) Mostly true   (4) Definitely true

21. How often do you feel hungry?

(1) Only at meal times   (2) Sometimes between meals   (3) Often between meals   (4) Almost always

22. Do you go on eating binges though you are not hungry?

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