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Individual differences in food-cue reactivity

by


Amanda Tetley

A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of Doctor of
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ABSTRACT

Previous studies have suggested that brief exposure to the sight and smell of food can elicit a momentary increase in desire to eat that food and can stimulate food intake. This thesis sought to explore individual differences in this 'food-cue reactivity.' Specifically, it aimed to explore associations between reactivity to food cues and i) dietary restraint (Experiments 1 to 6), ii) dietary disinhibition (Experiments 1 to 6), iii) everyday portion-size selection (Experiments 3 to 5), iv) body weight (Experiments 5 and 6), v) sensitivity to reward (BAS trait) (Experiment 6), and vi) impulsivity (Experiment 6). Using a typical cue reactivity paradigm, female students (Experiment 1 $n = 56$, Experiment 2 $n = 120$, Experiment 3 $n = 30$, Experiment 4 $n = 30$, Experiment 5, $n = 120$, Experiment 6 $n = 120$) from Loughborough University (aged between 18 and 30) were exposed to a food cue and then a series of subjective (appetite ratings), and behavioural (intake and desired portion size), markers of appetite were assessed.

Notably, two main findings emerged from this research. Firstly, there was little evidence to suggest that food-cue reactivity shared any association with dietary restraint status *per se*. Rather, sensitivity to reward, impulsivity, and dietary disinhibition, were identified as potentially important determinants of sensitivity to food cues. Secondly, some experiments (Experiments 3 and 5) suggested that food-cue reactivity might be elevated in individuals who are overweight, and who select larger everyday portion sizes. Based on these findings, conclusions are drawn regarding the potential mechanisms which might govern food-cue reactivity, and the possible consequences of greater reactivity for everyday food consumption. In particular, it is concluded that food-cue reactivity might result from a universal sensitivity to stimuli which predict the occurrence of a reward, and from an inability to exercise sufficient self-control in the presence of tempting environmental cues. In addition to this, it is also suggested that, over time, a greater susceptibility to the effects of food cues might contribute to, greater everyday food intake, and weight gain. To move forward within this research area, studies should continue to investigate the role of food-cue reactivity in overeating, and seek to further identify the mechanisms which promote greater reactivity to these cues.

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INTRODUCTION

Levels of obesity are reaching epidemic proportions worldwide. In England in 2004, 23.6% of men and 25.6% of women were found to be obese (BMI > 30). In addition to this, 43.9% of men, and 34.7% were reported to be overweight (BMI = 25-29.99) (Health Survey For England, 2004). Similarly, in the US, between the years of 1999 and 2000, 64.5% of the population were reported as overweight, and 30.5% as obese (Flegal, Carroll, Ogden & Johnson, 2002). This is particularly alarming since obesity is associated with increased mortality (Calle, Thun, Petrelli, Rodriguez, & Heath, 1999; Hu, Tuomilehto, Silventoinen, Barengo, Peltonen, & Jousilahti, 2005; Jain, Miller, Rohan, Rehm, Bondy, Ashley *et al*, 2005), a higher risk of cardiovascular heart disease (Cunliffe, Toyoshima, Date, Yamamoto, Kikuchi, Kondo, *et al*, 2005), Type II diabetes, sleep apnoea, hypertension, and cancer (WHO, 1998).

In light of these increases in levels of obesity there has been an increased interest in the factors that can motivate food consumption. Traditionally, it was assumed that physiological factors solely controlled food intake (e.g., Kennedy, 1953; Mayer, 1955). However, more recent evidence has suggested that external environmental cues associated with food ingestion also have the capacity to promote food consumption (e.g., Weingarten, 1983, 1984). These external cues might include food cues, such as the sight and smell of food which are present immediately prior to food ingestion, contextual cues including particular locations where specific foods are regularly eaten, and particular times of the day when meals are typically consumed.

The research presented in this thesis is primarily interested in the effect of environmental food cues, such as the sight and smell of food, on motivation to eat. To date, studies exploring this 'food-cue reactivity' have suggested that brief exposure to food-related stimuli, such as the sight and smell of food, can elicit a momentary increase in desire to eat and can stimulate food intake (e.g., Fedoroff, Herman, & Polivy, 1997; Nederkoorn, Smulders, Havermans, & Jansen, 2004).

However, despite this basic research, very few studies have sought to explore individual differences in this reactivity to food cues. An investigation of this kind might be important because it might enhance our understanding of both the causes and consequences of this dietary phenomenon. For this reason, this thesis considers individual differences in food-cue reactivity. Specifically, it explores associations between food-cue reactivity and everyday dietary behaviour, everyday portion-size selections, being overweight, and personality characteristics, such as impulsivity and sensitivity to reward. These associations are explored in a series of six experimental studies.

The subsequent chapters provide a detailed account of the background literature relevant to the research conducted here, and the details of each individual experiment including the methodologies employed, and a systematic review of the findings. In the next chapter, the importance of external food-cues in dietary control is considered. Following this, the second chapter considers the evidence for food-cue reactivity to date (Part I). It then identifies more clearly the questions addressed in this thesis, and discusses the literature relevant to these questions (Part II). Chapters 3-7 report the rationale, methodology employed, and the findings, for each of the six experiments. The final chapter (Chapter 8) presents a discussion of the combined results from these empirical experiments, evaluates the limitations of the work presented, and considers proposals for future research.

CHAPTER 1

EXTERNAL DETERMINANTS OF DIETARY CONTROL

1.1 Chapter Introduction

The primary aim of this chapter is to review the evidence pertaining to the role of external environmental stimuli in motivating food intake. The review begins by describing models of food intake which adhere to a purely physiological account of dietary behaviour, and by considering the limitations of these. This is followed by the identification of a theory which also recognises the potential contribution of non-physiological factors, such as environmental cues, in dietary control. After this, specific consideration is given to evidence suggesting that external sensory stimuli (e.g., the flavour of a food, or the sight and smell of a food) can control what, when, and how much, food is eaten. It is suggested that this occurs as these stimuli become associated with particular aspects of food ingestion (learned dietary responses). In the final part of this chapter, non-food specific theories of the learned mechanisms underlying externally-cued behaviour are discussed. These theories are reviewed here because they develop a broader understanding of the mechanisms which might govern responses to external food cues.

1.2 Set-point, and settling point, models of dietary control

Previously, it has been suggested that eating behaviour is controlled exclusively by physiological changes which signal the state of the body's energy resources (Kennedy, 1953, Mayer, 1955). Eating is assumed to occur when an energy deficit is perceived, and is terminated once energy resources are at their optimal level. According to this perspective, a set-point represents the ideal energy level of the

body. Actual physiological state can then be compared continuously with this set-point. If this comparison signals that energy resources are below this set-point, an error signal (negative feedback) will be produced. This signal will then promote food ingestion. Food ingestion will then continue until the set-point is reached. At this point a meal will be terminated. In this way, the set-point acts to maintain homeostasis, which literally means it maintains a stable internal state (Cannon, 1932)

Regulation of the set-point has been suggested to occur in one of two ways. Firstly, Mayer (1955) argued that energy status is signalled by glucose utilisation (glucostatic hypothesis). More specifically, he argued that energy depletion is signalled by glucoreceptor cells levels signalling zero. He suggested that once these levels are detected, eating behaviour is initiated. Consistent with this hypothesis, Rezek and Kroeger (1976) showed that manipulations which depress glucose utilisation (2-deoxyglucose, 2DG) often stimulate food ingestion. However, although Smith, Gibbs, Strohmayer, and Strokes (1972) confirmed that 2-deoxyglucose (2DG) stimulates eating behaviour, they also showed that ingestion occurs only when depletion falls to levels which are rarely observed in animals or humans. Thus, these findings can be taken to suggest that this mechanism is unlikely to regulate a set-point. A second hypothesis based upon the notion of a set-point is the lipostatic hypothesis (Kennedy, 1953). According to this hypothesis, a set-point exists for body fat levels. Thus, if body fat falls below the set-point, adjustments in eating will be made, such that body fat levels return to this set-point. In support of this model, research suggests that leptin could feasibly act as a negative feedback signal (Seeley & Schwartz, 1997). This is because, firstly, there are leptin receptors in the brain, and, secondly, circulating levels of leptin are correlated with adipose tissue in humans and animals. However, against the lipostatic hypothesis, it has been suggested that the accumulation of fat does not in fact appear to generate any biological drive to undereat (Blundell & Halford, 1994). Indeed, if it did, the dramatic increases in obesity recently observed are unlikely to have occurred.

Interestingly, Levitsky (2002) provides a clear argument against a set-point model of eating behaviour regulation. He quite rightly assumes that if a homeostatic system of eating behaviour exists, then intake at one meal should be contingent on the amount consumed at the previous meal, and also on the length of time since that meal. However, as Levitsky (2002) reveals, evidence from experimental work has not in fact supported this possibility. Firstly, it has been found that the amount of food an animal eats is not related to the pre-meal interval (Le Magnen & Tallon, 1963; Le Magnen, 1966, both cited in Levitsky, 2002). Secondly, several studies have found that the energy consumed by eating snacks between meals is not compensated for at standard meal times during that day (Morgan & Guegan, 1986, cited in Levitsky, 2002), and eliminating a meal does not encourage greater Kcalorie intake at other meals (Feldman & Levitsky, unpublished, cited in Levitsky, 2002).

Given the evidence against a set-point model of food intake, Wirtshafter and Davis (1977) proposed a settling point theory of eating behaviour. This theory suggests that weight tends to drift around a settling point. A settling point is a level at which the various factors that influence body weight achieve an equilibrium. These factors are likely to be hormonal factors, neural factors, and external environmental factors, such as food availability and palatability. According to a settling point model, body weight remains stable as long as no long-term changes in these factors occur. If there is a change in one of these factors, a new settling point will be reached as the other factors re-establish equilibrium. Therefore, according to this model, recent increases in obesity are unlikely to be due to higher physiological set points, but are likely to have occurred because environmental changes in food availability and palatability have forced new settling points to be reached (Berridge, 2004).

The importance of a settling point theory is that it suggests that physiology does not determine a fixed body weight. Rather, it acknowledges that other factors might also influence food intake, and consequently body weight. Consistent with this perspective, empirical evidence suggests that factors other than physiological signals do play an important role in dietary control. Amongst others, these non-physiological cues might include the taste of the food, learned responses to external cues, and social factors. For example, the number of people present at a meal can

influence the amount that is eaten (De Castro & Brewer, 1992), as can the available portion size of the food (e.g. Diliberti, Bordin, Conklin, Roe, & Rolls, 2004; Rolls, Morris, & Roe, 2002, Rolls, Roe, Meenings & Wall, 2004;), the palatability of a food (Decke, 1971, Rodin, 1975a; Yeomans, 1996), and the presence of attractive food cues (e.g., Fedoroff *et al*, 2004). Since the research presented in this thesis specifically aims to explore the effect of external food cues on motivation to eat, the remainder of this review will focus on evidence which suggests that sensory external stimuli (i.e., the flavour of a food and visual and olfactory cues) can gain the capacity to control food intake as they become associated with food ingestion (i.e., through learned associations).

1.3 The role of external sensory stimuli in dietary control

Learned associations between external sensory stimuli (i.e., the flavour of a food or visual and olfactory cues) and food ingestion have been found to be powerful determinants of dietary behaviour. The ability of stimuli to evoke behaviours, or responses, which they do not naturally elicit, was originally discovered by Ivan Pavlov in 1927. Following from this discovery, Pavlov (1927) formulated a theoretical account of this learned behaviour. He suggested that as a neutral stimulus becomes associated with a stimulus which elicits an unconditional reflexive response (unconditioned stimuli), this neutral stimulus eventually acquires the capacity to elicit this reflexive response. This response is therefore called a conditioned response (CR) and the previously neutral stimulus which elicits it is called the conditioned stimulus (CS). This form of learning is now typically referred to as Pavlovian, or Classical, conditioning.

Learned associations between the sensory characteristics of food and its ingestion occur in a similar way to that proposed by Pavlov (1927). Specifically, an external sensory stimulus (e.g., flavour of a food, visual or olfactory food cue) (CS) becomes *associated* with the already liked, or disliked, flavour (flavour-flavour learning), a feeling of satiety (learned satiety), or a feeling of reward (conditioned meal initiation) (UCS). Thus, on subsequent occasions these stimuli elicit a representation of the UCS which it has become associated with. Such associations have been

implicated in the establishment of flavour preferences (flavour-nutrient learning, flavour-flavour learning), meal termination (learned satiety), and meal initiation (conditioned meal initiation). Although this thesis aims to specifically explore conditioned meal initiation, it is important to consider the fundamental role that dietary learning might have, not only to meal initiation, but also for other aspects of dietary control. For this reason, the subsequent sections begin by considering the role of dietary learning in the establishment of flavour preferences, and meal termination. This is then followed by a review of the literature pertinent to conditioned meal initiation.

1.3.1 Flavour-flavour and flavour-nutrient learning

One form of dietary learning known to facilitate flavour preferences is referred to as 'flavour-flavour learning.' This is the result of a novel flavour (CS) being paired with an already liked, or disliked, flavour (UCS), such that the valence of the novel flavour shifts in the direction of the UCS. In this way, a novel flavour paired with an already liked flavour will become liked, while a flavour paired with a disliked flavour will become disliked. Several studies have suggested that pairing a novel flavour with an already liked flavour can evoke a preference for this previously neutral flavour in humans (Brunstrom, Downes & Higgs, 2001, Zellner, Rozin, Aron, & Kulish, 1983,) For example, Zellner, *et al* (1983) found that preference for a novel flavour (CS) was enhanced after being repeatedly paired with the sweet taste of sugar (UCS). Likewise, a number of studies have provided evidence to suggest that pairing a novel flavour with a disliked flavour can bring about learned dislikes. Baeyens *et al* (1988, 1990, 1996), for example, reported that liking for novel flavours decreases after being repeatedly paired with Tween 20, a rather distinctive disliked flavour.

Furthermore, flavour preferences might also be enhanced or inhibited by a different form of learning. Indeed, associations formed between a food's flavour and its postingestive consequences can facilitate or inhibit food preferences (flavour-nutrient learning) in humans and animals. For example, when a novel flavour (CS), is paired with reinforcing postingestive effects (UCS), this flavour will become

liked. Similarly, when a novel flavour is paired with aversive postingestive effects, such as nausea, or gastrointestinal illness, this flavour will become disliked and will be avoided on subsequent occasions (Logue, Ophir, & Strauss, 2002). Consistent with this, several studies have reported that pairing a novel flavour with a nutritive substance which is rewarding metabolically can enhance preference for this flavour in animals. In the first study to report this nutrient-based flavour learning in animals, Holman (1968) trained rats to drink a flavoured solution paired with an intragastric infusion of liquid diet (CS +), and another solution paired with intragastric infusions of water (CS-), in alternate sessions. When subsequently offered the two flavours in a two-bottle choice test, rats displayed a significant preference for the flavour previously paired with the liquid diet. Using a variation of this basic experimental paradigm, a large number of subsequent studies have also reported flavour preferences conditioned by intragastric infusions of complete diets or individual macronutrients (for e.g., glucose, polycose, casein, corn oil, ethanol) in deprived and non-deprived animals, trained in short (10-30 min) or long term (20-23hr) sessions (Booth, Stoloff, & Nicholls, 1974, Elizalde & Sclafani, 1990; Holman, 1968; Perez, Ackoff, & Sclafani, 1996, Perez, Fanizza, & Sclafani, 1999, Sclafani & Nissenbaum, 1988; Warwick & Weingarten, 1996).

Albeit relatively less sparse, in humans, similar conditioned flavour preferences have also been reported. For example, several studies have suggested that repeatedly pairing a novel flavour with the ingestion of energy in the form of protein, fat, or carbohydrate, can enhance liking for that flavour in both adults and children (Baker, Booth, Duggan, & Gibson, 1987, Booth, Mather, & Fuller, 1982; Gibson, Wainwright, & Booth, 1995, Johnson, McPhee, & Birch, 1991, Kern, McPhee, Fisher, Johnson, & Birch, 1993). For example, Gibson, *et al* (1995) conditioned participants to associate a novel-flavoured blancmange dessert with the postingestive rewarding consequences of protein over four conditioning trials. Surprisingly, even after the first of these trials, the authors found that liking for the dessert had increased significantly. In a similar study, Johnson, *et al* (1991) paired novel flavoured yoghurts with a high or a low fat content over eight conditioning trials. On test days, the authors found that the children's preference for the high-density paired flavour was enhanced. Since the flavour was presented in the absence of fat on this test day, it is clear that the change in preference was for the flavour

itself, not for the fat substance it had been paired with. Other substances known to offer a postingestive reward have also been found to facilitate flavour preferences in humans. For example, several studies have suggested that pairing caffeine with novel flavours can reinforce changes in flavour preference when individuals are caffeine-deprived (Richardson, Rogers, & Elliman, 1996, Yeomans, Durlach, & Tinley, 2005, Yeomans, Jackson, Lee, Steer, Tinley, Durlach, & Rogers, 2000b; Yeomans, Spetch, & Rogers, 1998; Yeomans, Jackson, Lee, Nesic, & Durlach, 2000a). Specifically, Yeomans, *et al* (1998) demonstrated that liking for a novel-flavoured drink increases significantly after it has been paired repeatedly with caffeine over several conditioning trials.

Similar associations formed between the flavour of a food and its postingestive properties can also come to control meal termination. As suggested above, a homeostatic model of meal termination proposes that a meal is ended when some physiological detector informs the brain that enough energy has been absorbed, and no further food needs to be eaten. However, nearly half a century ago, Le Magnen (1955) recognised that the answer could not be this simple. The reason for this is that food is emptied far more gradually from the stomach into the upper small intestine, where absorption takes place, than the rate at which it is eaten. Therefore, by the time a person terminates a meal very little energy has been absorbed (Carbonnel, Lemann, Rambaud, Mundler, & Jian, 1994) Given this, Le Magnen (1955) realised that ending a meal was in essence a prediction of later energy absorption based on what was being consumed. More recently, this idea has been formalised and is termed 'learned satiety' It refers to the fact that future anticipatory control of meal size occurs when the flavour of a food (CS) becomes associated with the foods postingestive consequences (UCS) (Booth, 1977; Stunkard, 1975,)

Experimental support for learned satiety originally comes from studies using rats (Booth, 1972; Davis & Campbell, 1973), and was also later reported in monkeys (Booth & Grinker, 1993) In an initial experiment, Booth (1972) presented rats with two flavours paired with different energy densities over a series of conditioning trials. In the test phase, the energy content was manipulated such that it was identical for each of these flavours It was set at a value between the two contents

presented in the conditioning trials. Not surprisingly, in the test phases the rats increased the size of their feeding bout on the flavour previously paired with the dilute nutrient, and reduced the size of their feeding bout on the flavour previously paired with the more concentrated nutrient. Since the rats cannot have been responding to real differences in the energy content in the test phase, their behaviour must result from the fact that the flavour paired with the more concentrated nutrient had come to *predict* greater feelings of satiety, therefore encouraging the rats to consume smaller amounts of this flavoured food. More recently, Gibson and Booth (2000) have also suggested that associations formed between the odour of a food and its postingestive after effects can come to control meal size in rats. In this study, the authors found that in a two-bottle choice test, rats drank more of a fluid which had a novel odour, than one which had previously been associated with a concentrated starch (maltodextrin) solution.

Following initial demonstrations of learned satiety in animals, flavour-postingestive associations were also found to determine meal termination in humans (Birch & Deysher, 1985, Booth, *et al*, 1982;). For example, Booth *et al* (1982) showed that if a soup flavour is repeatedly paired with starch augmentation across a number of training trials, *ad-lib* intake following this soup is subsequently reduced, despite the fact that the flavour is presented in the absence of starch augmentation. Again, this is because the previously novel flavour has come to predict greater feelings of satiety generated by starch ingestion.

Taken together, the evidence presented in this section suggests that particular sensory characteristics of a food, such as the taste of food, can gain the capacity to control flavour preferences and meal termination in animals and humans. This evidence is interesting because it highlights the importance of dietary learning for decisions made about what, and how much, to eat. However, most important to this thesis is how learned associations between external stimuli and eating might gain the capacity to control when individuals might initiate food intake. This learned phenomenon has received relatively less attention in the ingestive behaviour literature than other forms of dietary learning. Despite this, this issue merits consideration. This is because it is important to understand why individuals consume food when they do, particularly in light of the recent increases in obesity

(see Introduction) Therefore, the following section reviews the theories of conditioned meal initiation proposed to date.

1.3.2 Conditioned meal initiation

As suggested previously (see Section 1.3), Pavlov (1927) initially described how formerly neutral stimuli can come to elicit new responses after being associated with a stimulus which elicits this response (Pavlovian/ Classical conditioning). In forming his principles of Pavlovian (Classical) conditioning, Pavlov (1927) was in fact the first to suggest that learned associations between external food cues (visual and olfactory) and food ingestion can come to control appetite. While investigating neural mechanisms controlling glandular secretions during digestion in dogs, Pavlov (1927) found that the appearance of his laboratory assistant began to elicit salivary responses in these dogs. Pavlov assumed that the reason for this was that his laboratory assistant began to predict the food which the dogs would subsequently be given. To explore this possibility further, Pavlov placed inexperienced dogs in a harness and occasionally gave them small amounts of food powder. Before placing the food powder in the dog's mouth, Pavlov sounded a bell, a buzzer, or some other auditory stimuli (CS). After repeated pairings of the food powder and auditory stimuli the dog began to salivate in the presence of the auditory stimuli alone (CR). Thus, the auditory stimuli had come to predict the presence of food.

Following this early work by Pavlov (1927), several authors have theorised about the extent to which external stimuli might gain the capacity to motivate appetite and food intake (Weingarten, 1983, 1984, 1985; Woods 1991, Woods & Ramsey, 2000; Woods & Strubbe, 1994, Wardle, 1990). Identical to all these authors' theories is the idea that previously neutral environmental stimuli (CS) can stimulate food intake (CR), after these stimuli have been repeatedly paired with food consumption (UCS). Weingarten (1983, 1984, 1985) called this appetitive motivation elicited by an external cue 'incentive-induced hunger'. By contrast, Wardle (1990) suggested that environmental stimuli in fact elicit a biological state which is similar to 'real hunger.' She called this 'deprivation-induced hunger,' and emphasised the physiological changes that this might involve. Similar to Wardle's (1990)

perspective, Woods and colleagues (Woods 1991, Woods & Ramsey, 2000; Woods & Strubbe, 1994) have referred to a cue-elicited motivation to eat as anticipatory hunger. They (Woods 1991; Woods & Ramsey, 2000, Woods & Strubbe, 1994) suggested that external stimuli (e.g., time of day) which signal food intake, are followed by physiological changes which prepare the body for food ingestion. These signals are then interpreted as feelings of hunger.

Experimental support for this learned meal initiation comes from several studies which have suggested that cues which have been paired with food ingestion over a number of conditioning trials can stimulate meal initiation, and can elicit instrumental responding for food, in both animals (Calvin, Bicknell, Sperling, 1953; Edgar, Hall, & Pierce, 1981; Flatt & Bailey, 1983, Lovibond, 1983; Lovibond, 1980; Zentall, Hogan, Compomizzi, & Compomizzi, 1976; Weingarten, 1983, 1984), and humans (Birch, McPhee, Sullivan, & Johnson, 1989). Specifically, Weingarten (1983, 1984) found that stimuli conditioned to food ingestion can determine when rats will initiate a meal and the amount of food they will consume. In these studies, rats were typically fed a liquid diet in six irregularly spaced meals each day. During this training phase each meal was signalled by a buzzer and a light (the conditioned stimuli CS+) presented for four minutes before, and 60 seconds after the meal was made available. In the test phase the CS+ was presented while rats were non-food deprived. The rats responded 'rapidly and robustly' to the CS+ by taking a meal which was approximately 20% of their total daily Kcalorie intake. In contrast, they did not respond to another stimulus (a steady tone CS-) which had been present exactly midway in each inter-meal interval. For Weingarten (1983, 1984), these findings suggested that external cues associated with food ingestion gain the capacity to stimulate food ingestion even in the absence of nutritional need.

In a similar study using human participants, Birch *et al.* (1989) found that children were more motivated to eat in the presence of cues which had been previously paired with food consumption. In this study, the authors trained preschool children to associate the presence of a red rotating light, a particular piece of music, and a specific location (external stimuli) with the consumption of snack foods. They did

this by presenting these external stimuli for 30 seconds before food presentation, and for four and a half minutes after this food had been made available. During the test trials, the conditioned stimuli was presented to the children while they were satiated. In these trials all fifteen children ate immediately in the presence of the conditioned stimuli and consumed meals that comprised 10% to 15% of the Recommended Daily Average (RDA) of Kcalories for children of this age. In contrast, when the children were presented with stimuli which had not been paired with the consumption of snack foods during conditioning trials, only three out of 15 of the children began to eat the snack foods immediately, and on average they consumed smaller amounts of these foods.

Thus, taken together, the findings reviewed here suggest that external stimuli can in fact be conditioned to motivate eating behaviour. A more detailed review of these conditioned responses is considered in Chapter 2. However, the remainder of this chapter considers food-cue reactivity in relation to non-food specific theories of motivated behaviour.

1.4 Non-food specific theories of motivated behaviour

The idea that external stimuli can motivate behaviour is not exclusive to dietary control. Rather, external stimuli are assumed to control much of our motivated behaviour. For example, it might control drug-taking behaviour, sexual behaviour, attention-seeking behaviour, behaviour motivated towards social approval etc. For this reason, a number of theories have been proposed to explain how external stimuli generally gain the capacity to motivate behaviour. The subsequent sections will provide an historical review of these theories, and identify how they might inform our understanding of conditioned meal initiation.

1.4.1 Instrumental/Operant conditioning

The first author to discuss motivated behaviour in response to external stimuli was Thorndike (1905, 1908, 1911). He described a form of learning known as ‘operant,’ or ‘instrumental,’ conditioning. Essentially, this form of learning suggests that organisms engage in behaviours associated with particular stimuli (such as a string or lever) if these behaviours have previously resulted in desirable consequences such as *food*, a drug, attention, or social approval.

Thorndike’s ideas were based exclusively upon his observations from experimental work. In this work, Thorndike typically placed hungry cats in so-called ‘puzzle boxes.’ These boxes contained a dangling piece of string, which when pulled released the cage’s latch, allowing the cats out of the box where they received a bowl of food. When first placed in the puzzle box, a cat would claw and bite at the confining bars and wire. Through random trial and error behaviour, the cat would eventually pull the string and open the cage to reach the food. When placed in the box again, the cat would pull the string more quickly, until after several trials, the cat would pull the string immediately when placed in the box. The reason for this is that pulling the string had become reinforced by the reward of eating the food. Thus, the previously neutral string had acquired motivational properties and consequently was able to elicit the ‘pulling’ behaviour.

Following Thorndike’s theorising, Skinner (1938, 1953) proposed a similar model. Like Thorndike, he also suggested that some events which follow responses have the effect of increasing the likelihood that the response will be repeated. Again, Skinner (1938, 1953) was able to show that a previously neutral stimuli (a lever) could gain the capacity to motivate an instrumental response because it was associated with a reward, i.e., a food pellet.

1.4.2 Drive reduction theories

Later theorists (e.g., Guthrie, 1934, 1952; Hull, 1935, 1943, Tolman, 1932) continued to suggest that environmental stimuli could gain the capacity to motivate behaviour. However, they also went on to suggest that previously neutral environmental stimuli elicit these behaviours because they become associated with a drive reduction. For example, they were suggesting, that if pressing a lever results in the administration of food, the lever will become associated with a reduction in hunger drive. Likewise, if it is associated with water it will become associated with a reduction in thirst drive. Thus, on occasions where organisms are hungry, or thirsty, environmental stimuli which are associated with a reduction in these drives will be approached and behaviour to reduce this drive will be initiated. By contrast, in circumstances where individuals are not hungry or thirsty, these stimuli will not be approached. For Tolman (1932), learning about these associations between environmental stimuli and a particular drive reduction results in environmental stimuli gaining the capacity to elicit an 'expectancy' of the forthcoming 'reward' or 'reduction in drive.' This expectancy arises from memories of previous occasions where a particular stimulus has preceded a reduction in a particular drive or motivation and it is this expectation which subsequently motivates behaviour.

1.4.3 Incentive motivation

Following from these drive reduction theories, a series of authors suggested that rather than signalling drive reduction, neutral environmental stimuli in fact acquire incentive motivation (e.g., Bindra, 1974, Bolles, 1972;). Thus, the stimuli come to signal a tasty reward, rather than a reduction in hunger drive. For example, one incentive motivation theorist, Bolles (1972), suggested that this incentive motivation is an expectation of a pleasurable reward. What is learned, according to Bolles (1972), therefore, is a contingency between certain previously neutral environment stimuli (S) and a hedonic reward (S*), such as a tasty food. The previously neutral stimuli therefore elicit an 'expectancy' of the preceding reward.

This cognitive expectancy is similar to that proposed by Tolman (1932), and is generated by memories of previous experiences of this hedonic reward

Contrary to Bolles (1972), Bindra (1974), another incentive motivation theorist, suggested that rather than causing an expectation of a hedonic reward per se, environmental stimuli associated with a hedonic reward in fact elicit the same incentive motivational state normally caused by the reward itself. Thus, according to Bindra (1974), the previously neutral stimuli *gains* incentive value. This contrasts Bolles (1972) theory which suggests that the stimuli only gains an expectation of the reward, and does not acquire incentive motivation itself. In an illustration of Bindra's (1974) theory, he suggested that after repeatedly pairing a light with the presentation of food, the light will come to elicit a representation of the rewarding effects of the food, and thereby has gained incentive value. In this way, previously neutral environmental stimuli can come to elicit motivational arousal. According to Bindra (1974), this arousal consequently elicits goal-directed behaviour to obtain the reward associated with this incentive motivation.

1.4.4 Incentive salience

More recently, the notion of incentive salience (Berridge, 2004; Berridge & Robinson, 1998) has been proposed to explain how environmental cues can come to motivate particular behaviours. Importantly, this concept follows Bindra (1974) and Toates (1981) rules for incentive conditioning (Berridge, 2004). It suggests that once incentive salience has been attributed to an external stimulus, on subsequent occasions when this cue is encountered, the incentive associated with that cue will become highly salient. However, perhaps the greatest distinction between this theory and the incentive motivation theories described above is that it suggests that 'liking' and 'wanting' a reward are not synonymous, and that it is in fact wanting, not liking, which motivates responding to incentive stimuli.

For Berridge and colleagues, 'liking' essentially refers to sensory pleasure. It is triggered by the immediate receipt of a reward, such as a sweet taste. It can also be triggered by a CS as this predicts a hedonic reward, but it is not capable of

motivating behaviour towards this reward. In contrast to this, 'wanting,' or incentive value, reflects the motivational incentive value of the same reward, and is not a sensory pleasure. This wanting system is therefore able to attribute incentive salience to previously neutral stimuli. When this incentive salience is attributed to a reward representative, it makes that stimulus attractive, and attention grabbing.

This 'incentive salience' model results from findings from neurological studies. These studies have suggested that brain dopamine is activated by the sensory pleasure of a reward. However, Berridge and his colleagues (Berridge, 2004; Berridge & Robinson, 1998;) have reviewed a body of evidence which suggests that manipulations of mesolimbic/neostriatal dopamine systems (through blocking dopamine, or electrically stimulating dopamine) modify motivation to eat (wanting), but fail to alter liking measured by hedonic or aversive reaction patterns. On the basis of this evidence, they concluded that hedonic reaction (liking) and incentive motivation are two separable constructs and that only the latter of these is involved in responding to environmental stimuli.

The incentive salience hypothesis specifies that the attribution of incentive salience involves three distinct psychological processes. The first of these is 'hedonic activation'. In this stage, novel stimuli trigger hedonic pleasure or liking. Thus, an individual might eat a food which triggers a hedonic response. The second stage is 'associative learning.' In this phase, associative learning identifies the correlation between the hedonic activation (i.e., liking for the food) and the predictive external event or conditioned stimulus that preceded it. Therefore, taken together, these first two stages are sufficient to associate the CS with a hedonic response. However, these processes alone do not suffice to make a CS attractive or to motivate behaviour towards it. They simply make it possible for the CS to activate an affective state. The final stage involves attribution of incentive salience. Incentive salience is required to transform the 'neutral' perception of a conditioned stimulation into an attractive incentive capable of eliciting appetitive or instrumental behaviour towards it. Only on this final stage does the stimulus event become 'wanted' as well as 'liked'. This occurs as incentive salience is attributed to the stimuli by activation of dopamine-related systems guided by associative learning. Interestingly, Berridge and Robinson (1998) also suggest that on each subsequent

encounter with a 'wanted' and 'liked' stimulus, its capacity to support wanting is maintained or strengthened by associative 'reboosting' of the incentive salience assigned to the representation. Reboosting occurs when a wanted incentive is followed again by activation of hedonic liking. If reboosting occurs the reward will again be 'wanted' on later occasions.

1.4.5 Relevance of non-food specific learning theories for dietary control

The literature reviewed here relating to non-food specific theories of learned motivated behaviour suggests that previously neutral environmental stimuli can elicit conditioned responses either through a process of drive reduction, whereby behaviour associated with a particular behaviour is known to reduce a specific drive, by eliciting expectancy or a representation of a hedonic reward, or by gaining incentive salience. Therefore, these theories provide alternative views of the process by which an external cue might gain the capacity to motivate eating behaviour.

A drive reduction theory of food-cue reactivity would suggest that an external stimulus associated with food ingestion signals a reduction in hunger. Thus, when individuals are hungry they are likely to approach these stimuli to reduce their hunger drive. However, according to this theory, in the absence of hunger these stimuli are likely to be ignored. Yet, evidence relating to conditioned meal initiation reviewed in Section 1.3.2 suggested that external cues which have been associated with food intake elicit eating behaviour in both satiated, rats (Weingarten, 1983, 1984) and humans (Birch *et al* , 1989). Therefore, it is unlikely that this theory provides an accurate account of the mechanism underlying food-cue reactivity.

Contrary to the drive reduction theory, incentive motivation theorists (e.g , Bindra, 1974), suggest that a food cue gains incentive motivation. This would therefore elicit a motivation to eat. Somewhat similar to this, Berridge and colleagues' (Berridge, 2004; Berridge & Robinson, 1998;) Incentive Salience hypothesis suggests that a cue previously associated with food ingestion gains incentive salience by activation of dopamine-related systems guided by associative learning. This incentive salience then guides attention towards the cue and makes it attractive.

Since the drive reduction theory was rejected here as an explanation of the process by which external cues motivate eating behaviour based on existing evidence in the literature, it seems appropriate to adhere to an incentive motivation account of conditioned meal initiation. Notably, to date, the literature pertaining to food-cue reactivity provides little evidence to reject this potential explanation. Therefore, one possibility is that an external cue which has become associated with food intake signals the availability of an incentive. This would thereby be sufficient to motivate eating behaviour to gain this reward.

1.5 Chapter summary

The evidence reviewed in this chapter suggests that a set-point model of dietary control is not sufficient to account for the complexity of eating behaviour. Rather, it suggests that it more plausible that body weight settles at the point at which internal physiological factors and external environmental stimuli achieve equilibrium. It has been suggested that external cues such as the sensory characteristics of a food can gain the capacity to influence dietary choices, meal termination, and meal initiation. This occurs as these characteristics become associated with particular aspects of food ingestion. For example, it was suggested that an already liked, or disliked, flavour can facilitate food preferences, or food aversions (flavour-flavour learning). Likewise, associations formed between a novel flavoured food and its reinforcing, or aversive, postingestive effects can determine our preference for this novel flavour (flavour-postingestive learning), and meal termination (learned satiety). Finally, and most importantly to this thesis, visual and olfactory food cues associated with food ingestion have been found to elicit a motivation to eat.

In this chapter, various theories of externally-cued motivated behaviour which are not specific to eating behaviour have also been reviewed. These theories suggest that previously neutral environmental stimuli can elicit conditioned responses either through a process of drive reduction, whereby behaviour associated with a particular cue is known to reduce a specific drive, by eliciting an expectancy or a representation of an hedonic reward, or by gaining incentive salience. These theories were referred to in this chapter to enhance understanding of the process by

which a conditioned cue comes to motivate eating behaviour. Since experimental evidence was not found to support the view that cues signal a reduction in hunger drive; one possibility is that conditioned cues signal the availability of a food incentive and thereby motivate eating behaviour.

CHAPTER 2

CUE REACTIVITY

2.1 Chapter Introduction

In Chapter 1 evidence was reviewed which suggested that an external stimulus can gain the capacity to motivate food intake after it has been associated with food ingestion (conditioned meal initiation). The aim of this chapter is to provide a more detailed review of the evidence pertaining to these conditioned responses (cue reactivity), and to identify how these findings are related to the questions addressed in this thesis

This chapter is divided into two parts. Part I provides a detailed review of evidence suggesting that external stimuli can motivate appetitive responses. Most importantly, this includes a discussion of evidence suggesting that cues associated with food intake can elicit a motivation to eat. However, prior to this, it considers the ability of external cues associated with drug use to stimulate drug-taking behaviour. This literature is particularly relevant to the research undertaken for this thesis because 'drug-cue reactivity' relies on similar learned associations as food-cue reactivity. Following these reviews, Part II of this chapter presents the literature relevant to the specific questions addressed in this thesis.

PART I

2.2 Drug-cue reactivity

When exploring dietary phenomenon it is important to consider other behaviours which rely on similar principles. Therefore, it is particularly relevant to this thesis that drug cues are also assumed to gain the capacity to initiate, and increase, drug-taking behaviour. Indeed, the effect of drug cues on drug use has been explored extensively in the drug literature. Typically, studies have suggested that exposure to drug-related cues can elicit a desire, or urge, for the cued drug, can stimulate greater use of this drug, and can increase physiological responsiveness, such as heart rate, and blood pressure in heavy users. This cue reactivity has been found to occur in the presence of stimuli associated with a range of drugs, including alcohol, tobacco, opiates, and cocaine

Studies exploring drug-cue reactivity typically expose participants to either, a drug cue, such as the sight of the drug itself or paraphernalia associated with the drug, (e g., a hypodermic needle), or to a neutral cue or 'no cue' (control condition), for a fixed amount of time. After this, a range of subjective, behavioural, and physiological, measures are assessed. These responses are then compared between the two conditions (no cue and drug-cue) and across heavy users of the drug, and light, or non-users.

In the alcohol-cue reactivity literature, for example, participants are typically exposed to an alcoholic drink, which might be their favourite drink (e g., Cooney, Litt, Morse, Bauer, Gaupp, 1997) or their most commonly consumed beverage (e g., Staiger & White, 1991), or they are exposed to a context which they associate with drinking, for example a bar (e g., Wigmore & Hinson, 1991). Their responses to these cues are then compared to their reactivity to neutral cues (e g. a non-alcoholic drink, or laboratory setting) and relative to the responses observed in social

drinkers. Using this paradigm, several studies have suggested that alcoholics report greater craving for alcohol, or a greater urge to drink alcohol (Cooney, Gillespie, Baker, & Kaplan, 1987, Greenley, Swift, Prescott, & Heather, 1993; Payne, Rappaport, Smith, Etscheidt, Brown, & Johnson, 1992; Pomerlau, Fertig, Baker, & Conney, 1983; Wiesbeck, Weijers, & Gross, 2000), experience increased heart rate (Breteler, Schippers, De Jong, & van der Stark, 2000; Payne *et al.*, 1991), have greater event-related potentials (ERP's)¹ (Herrman, Weijers, Wiesbeck, Boning, Fallagatter, 2001) experience increased salivation (Gulliver, & Sirora, 1994; Pomerlau *et al.*, 1983, Rubonis, Colby, Monti, Rohsenow,) and consume greater amounts of alcohol in relation to those exposed to a neutral cue (Wigmore & Hinson, 1991). These findings occur across age groups, as even alcoholic adolescents (aged 14-19) are found to experience greater craving and salivation while holding and sniffing their favourite alcoholic drink (Thomas, Drobes, & Deas, 2005). They are also found irrespective of detoxification (Staiger & White, 1991), or previous treatment (Pomerlau *et al.*, 1983).

Similar to alcohol-cue reactivity, reactivity to smoking cues has also been found to be elevated in smokers, relative to non-smokers, in the presence of smoking-related cues such as smoking paraphernalia (e.g., Rikard-Figuero, & Zeichner, 1985), contexts where smoking previously occurred (e.g., Thewissen, van der Hout, Havermans, & Jansen, 2005), cigarettes (Herman, 1974), or virtual reality smoking cues (Bordnick, Graap, Copp, Brookes, & Ferrer, 2005). Specifically, after exposure to such stimuli, smokers report a greater urge to smoke (Burton & Tiffany, 1997; Drobes & Tiffany, 1997; Field, & Duka, 2005; Hutchinson, Niaura, & Swift, 1999; Thweissen *et al.*, 2005), experience increased salivation (Field & Duka, 2005), greater skin conductance levels (Burton & Tiffany, 1997), increased heart rate (Rikard-Figueroa, & Zeichner, 1985), and are more likely to initiate smoking (Herman, 1974) and to smoke more quickly (Droungas, Ehrman, Childress, & O'Brien, 1995). Similar physiological, behavioural, and subjective, responses have also been reported in cocaine and opiate users. In particular, in the presence of drug-related cues (e.g., drug-related slides, videos, or objects) these drug users when

¹ An event-related potential is electrical activity produced by the brain in response to sensory stimuli or associated with the execution of a motor, cognitive, or psychophysiological task

compared to non-users, have shown significant increases in heart rate, skin conductance level, pupil dilation, and craving for drugs (Franken, de Haan, van der Meer, Haffmans, & Hendrick, 1999, Hugdahl & Ternes, 1981; Kranzler & Baller, 1992; Sideroff & Jarvik, 1980, Teasdale, 1973).

Similar to food-cue reactivity, this reactivity to drug-related cues is also assumed to result from associations formed between the cue and drug use. In fact, several theories of this learned behaviour have been proposed. These differ primarily in their conception of the representation elicited by the drug-related stimuli after learning has occurred. Some suggest it represents a drug-like response, while others have suggested that it represents a drug-opposite effect, or a drug withdrawal-like state.

In an early model of drug-cue reactivity proposed by Wikler and colleagues (Wikler, 1948; Wikler & Pescor, 1967), it was suggested that environmental stimuli become associated with the withdrawal effects of the drug (conditioned withdrawal model). Accordingly, when subsequently encountered, these environmental stimuli elicit withdrawal-like effects, which act as a drive to obtain the drug. In support of this model, studies have shown that drug-withdrawal can be conditioned in both humans and rats. For example, Wikler and Pescor (1967) found that rats made dependent on morphine and then transferred to a regimen in which a single high dose was given at the start of the day, lead to a daily cycle of withdrawal. In a similar study, O'Brien (1976) showed that opiate withdrawal symptoms can also be conditioned in humans.

In contrast to the conditioned withdrawal model, Siegel (1999) proposed a compensatory conditioning model. In this model, Siegel (1999) suggested that environmental stimuli become associated with compensatory, or adaptive, drug responses that serve to counteract the drugs effects. For Siegel, it is these drug compensatory responses which consequently stimulate drug use. Consistent with this model, McCaul, Turkhan, and Stitzer (1989) reported drug-like physiological responses in alcoholics after exposure to a drink which on previous occasions contained alcohol. In this experiment, alcoholic participants were given a dose of alcohol for four days, before substituting a placebo drink on a fifth day. A control

group experienced the placebo drink on each of the four days and also on the fifth test day. For the experimental group, in which the vehicle drink was intended to be CS (conditioned stimuli) for alcohol delivery, there was a fall in heart rate and skin conductance relative to controls following the placebo drink on the test day. Since these physiological responses are opposite to the assumed effect of alcohol, this was taken as evidence of drug-opposite conditioned effects.

While the conditioned withdrawal and compensatory conditioning models differ in their conceptualisation of the conditioned stimuli, they both regard the conditioned response as a motivational drive to procure drugs in an attempt to correct a need state. However, an alternative possibility proposed by Stewart, de Wit, and Eikelboom (1984) is that environmental stimuli paired with drug use come to elicit drug-like conditioned responses. It is these conditioned responses which Stewart *et al.* (1984) propose create a motivational state similar to that caused by the drug itself. This motivational state consequently acts as a 'priming' dose and stimulates drug use. This model has been referred to as the 'conditioned incentive model,' since it presumes that environmental stimuli become associated with the incentive, or reinforcing, value of the drug. (This theory is similar to more general scientific incentive learning theories reviewed in Chapter 1, Section 1.4.3). In support of this model, Schwartz and Cunningham (1990) reported drug-like responses in rats exposed to stimuli which previously signalled morphine infusion. In this study, rats were infused with morphine through an indwelling catheter, and temperature responses were monitored. In the experimental group, the infusion was given 30 seconds after the onset of a light and white noise lasting 15 minutes. In the control group, the drug was given 75 minutes after the onset of light and noise. Thus, for the experimental group the conditioned stimuli predicted the onset of the drug effects, whereas this contingency was absent for the control group. In the test session, the infusion was delayed in order to observe responding to the conditioned stimuli. The authors found that the expectation of the morphine infusion produced an increase in body temperature similar to that observed when the morphine had previously been infused. According to Stewart *et al.*'s (1984) model these drug-like effects experienced by the rats provided an incentive to obtain the drug.

In light of these three differing models of drug-cue reactivity, several authors have attempted to evaluate the evidence in support of each model. However, findings from cue reactivity studies typically provide support for all three models. For example, a number of studies have suggested that participants report withdrawal-like symptomology after drug-cue exposure (Powel, Gray, & Bradley, 1993, Staiger & White, 1991), and also experience physiological responses consistent with a withdrawal state (e.g., increased skin conductance) (Glautier & Drummond, 1994). Similarly, other studies report drug-opposite responses after exposure to drug-related stimuli (MacFarlane & White, 1989; Newlin, 1985, Staiger & white, 1988). For example, Newlin (1985) found that exposure to alcohol cues causes a fall in heart rate and skin conductance level, responses which are opposite to those reported after alcohol consumption (Nauria, Rohsenow, Blinkoff, Monti, Pedraza, & Abrams, 1988). And finally, several studies have also reported increased drug-like responses after exposure to alcohol, including increased skin conductance, heart rate responses, and intoxication, (Newlin, 1985). However, in reviews of the literature, Stewart *et al.*'s (1984) incentive model is typically found to receive the most empirical support (Glautier & Remington, 1995; Nauria *et al.*, 1988,). In a recent meta-analysis of 41 cue reactivity studies, Carter and Tiffany (1999) found that the profile of significant conditioned responses across all drugs of abuse (i.e., smoking, alcohol, heroin, cocaine) was characterised by increases in heart rate, increases in sweat-gland activity, and decreases in skin temperature. Given that these responses are the same as those that would be observed after ingestion of the drug itself, the authors viewed this finding as suggesting that the conditioned response elicited by exposure to a drug cue constitutes an incentive-motivational state. This is interesting because it is similar to conclusions drawn in Chapter 1 regarding food-cue reactivity. In Chapter 1 it was suggested that the process by which food cues gain the capacity to stimulate food intake might be via a process of incentive salience. Therefore, this suggests that the underlying process by which drug and food cues gain the capacity to motivate behaviour could be similar.

2.2.1 Drug-cue reactivity summary

Evidence reviewed in the previous section suggests that brief exposure to a cue associated with drug use can elicit physiological responses, induce urges and craving for the drug, and can encourage drug use by eliciting an incentive-motivational state. This evidence is relevant to this thesis because similar (but food-specific) responses are reported after individuals have been exposed to food cues. These food-specific responses will be reviewed in detail in the following section.

2.3 Food-cue reactivity

Contrary to drug-cue reactivity, food-cue reactivity has been explored less extensively. This is surprising because exploring food-cue reactivity might in fact enhance our understanding of eating behaviour. More specifically, it might provide one explanation for why some individuals are more susceptible to weight gain and overeating than others. To date, studies which have begun to explore the possibility of food-cue reactivity have followed the drug-cue reactivity literature and have focused primarily on the effects of exposure to a food-cue, such as the sight and smell of food, or thought of food, on physiological, subjective, and behavioural, eating-related responses

Using this cue reactivity paradigm, a range of physiological responses have been found to increase after food-cue exposure. For example, Nederkoorn, Smulders, and Jansen (2000) found that exposing participants for 16-minutes to three plates of diverse kinds of their favourite food, and asking them to look at it, to smell it, to imagine how it would taste (exposure period), and finally to taste the food (intensified exposure period), stimulated increases in heart rate, heart rate variability (HRV), salivation, blood pressure, skin conductance, and gastric activity. Likewise, Nederkoorn and Jansen (2002) reported similar increases in heart rate, gastric activity, and salivation in some of their participants (unrestrained eaters) after exposure to a variety of foods. Since Cephalic Phase Responses (CPRs) are elicited during exposure to a food cue to prepare the body for food ingestion, Nederkoorn *et*

al (2000) suggest that these CPRs were elicited in response to the food cue to gear the body up for food ingestion.

Similar to both Nederkoorn *et al* 's (2000) and Nederkoorn and Jansen's (2002) findings, Nederkoorn, Smulders Havermans, and Jansen (2004) found that asking participants to intensively smell their favourite foods elicited increases not only in heart rate and skin conductance, but also stimulated decreases in finger pulse amplitude (FPA). According to the authors, this reduced FPA presumably results from the fact that after food-cue exposure blood flowing to the intestines increases in anticipation of digestion of the expected food.

Other studies have focused primarily on the effect of food-cue exposure on salivation. For example, Brunstrom, Yates, and Witcomb (2004) and Tepper (1992) explored changes in salivation after brief exposure to the sight and smell of pizza, and found that exposure to this food cue was able to stimulate salivary responses. Other authors have conducted similar studies (e.g., Hodgson & Greene, 1979; Lappalainen, Sjoden, Karhunen, Gladh, & Lesinska, 1994) using chocolate. However, they have found that mere exposure to the sight of this food does not elicit salivation. Rather, only priming with the taste of chocolate was found to elicit salivary responses in these studies. The reason for this might be that by not having the same olfactory qualities as pizza, chocolate is unable to readily stimulate the same salivary responses that a food like pizza can stimulate. Consistent with this, a study conducted by Overduin, Jansen, and Eilkes (1997) exploring physiological responses to pictures of participant's favourite food did not report increases in heart rate, or skin conductance levels, suggesting that mere pictures of food might also have an inability to elicit a 'preparedness to eat.'

It is perhaps feasible to conclude that if food-cue reactivity can elicit a physiological preparedness to eat, it also elicits a subjective appetite to eat and stimulates food intake. However, since some food-cue reactivity studies have found that physiological responses do not correlate well with subjective and behavioural measures (e.g., Nederkoorn, *et al*, 2000, Nederkoorn & Smulders, 2002; Nederkoorn, *et al*, 2004), it is important that studies also explore the effects of cue exposure on subjective, and behavioural, measures separately. A number of studies

have done this and have reported momentary increases in food craving, desire to eat, and also hunger, after food-cue exposure. For example, Nederkoorn and Jansen (2002) found that craving increased to a greater extent after exposure to a food-cue, relative to craving experienced after exposure to a bar of soap (neutral cue). Likewise, several other studies have found that exposure to the sight, smell, and taste of, participants favourite foods, or slides depicting these foods, can elicit general food craving (Alsene, Li, Chaverneff, & de Wit, 2003, Nederkoorn, *et al*, 2000; Nederkoorn, *et al*, 2004; Overduin, *et al*, 1997; Sobik, Hutchinson, & Craighead, 2005). Furthermore, other studies have suggested that exposure to pictures of food, food itself, the taste of food, and written food cues, can stimulate feelings of hunger (Oakes & Slotterback, 2000), a desire to eat (Lambert, Neal, Noyes, Parker, & Worrell, 1992; Oakes & Slotterback, 2000), and can reduce feelings of fullness (Oakes & Slotterback, 2000).

In addition to reporting increases in subjective appetite after food-cue exposure, several studies have also suggested that food-cue exposure can stimulate intake of the cued food. In one such study, Fedoroff, *et al* (1997) exposed 91 food-deprived participants (two hours food-deprived) to either no cue, an olfactory food cue, a cognitive food cue, or a combination of the two types of food cues for ten minutes. In the olfactory cue condition, the smell of baking pizza wafted into the testing room, while in the cognitive cue condition, participants were instructed to think about pizza and were asked to record these thoughts on paper. The results suggested that exposure to the smell and thought of pizza separately, stimulated subjective appetite and also encouraged greater pizza consumption, as did exposure to a combination of these cues.

Notably, in the studies reported above, participants were tested while they were neither hungry nor satiated. However, in other studies the effects of food-cue exposure have been tested in satiated participants. One example of this is a study conducted by Cornell, Rodin, and Weingarten (1989). In this study, participants were offered a buffet lunch prior to cue exposure to ensure that they were non-food deprived. Rather than following a basic cue reactivity paradigm, and exposing participants to either no cue or a food cue, the authors cued all participants with the sight of one of two target foods (pizza or ice-cream). Thus, when exploring

evidence for cue reactivity in non-deprived participants, Cornell *et al* (1989) assumed that when satiated participants should eat nothing, and consequently compared consumption in this group to zero. Using this procedure, the authors found that intake was significantly greater than zero in their satiated group. They therefore concluded that cue exposure was able to stimulate intake even in the absence of nutritional need. However, this conclusion was flawed because Cornell *et al* (1989) assumed that individuals would eat nothing when satiated, despite a lack of evidence for this proposal. Consequently, it is unclear whether increased intake in Cornell *et al*'s study was in fact a result of cue exposure, or whether similar results would be observed even in the absence of this exposure. For this reason, it is important for studies to include a control condition. Herman, Ostovich, and Polivy (1999) did this in their study exploring changes in subjective appetite (hunger) after exposure to a food-related cue in hungry, and satiated, participants. Seventy-five food-deprived and non food-deprived participants were exposed to a food video showing a restaurant review depicting appetizing foods, such as pancakes, waffles, hamburgers, eggs, and pie, an engaging non-food video (no-cue/comedy), and a non-engaging neutral video (no-cue/weather). For both deprived and non-deprived participants, exposure to the food video significantly increased hunger ratings compared to the neutral video, suggesting that even in the absence of nutritional need, exposure to a food cue can stimulate subjective appetite. In support of this finding, in a more recent study, Marcelino, Adam, Couronne, Koster, and Siefferman (2001) reported greater increases in desire to eat after exposure to a pizza cue even when individuals reported low levels of hunger.

2.3.1 Food-cue reactivity summary

The evidence reviewed in this section suggests that exposure to the sight, smell, or thought of food can elicit a momentary increase in desire to eat, a physiological preparedness to eat, and can stimulate food intake. Despite this basic research, very few studies have recently sought to develop understanding of this dietary phenomenon further. Therefore, this thesis presents an attempt to do this. In the following part of this chapter the specific questions which were addressed in this thesis are considered.

PART II

2.4 Introduction

The aim of the second part of this chapter is to present the rationale for considering the specific questions addressed in this thesis. These questions emerged as the thesis progressed. Therefore, in the first section, an overview of the development of the thesis is provided. The purpose of this is to introduce the questions of interest before providing the rationale for considering each of these in the remaining sections of the chapter.

2.5 Overview of the issues considered in this thesis

Broadly, this thesis considers individual differences in food-cue reactivity. Following directly from previous research which will be discussed below, the initial experiments were designed to determine the extent to which differences in everyday dietary behaviour (dietary restraint and disinhibition) predict food-cue reactivity. After these initial experiments, a series of further studies were designed to explore the more complex issues related to this dietary phenomenon. One possibility considered was that food-cue reactivity has implications for everyday food consumption and BMI. Therefore, a series of experiments explored the potential links between reactivity to food cues and everyday portion-size selections, and being overweight. Another possibility which emerged after conducting these studies was that food-cue reactivity might in fact be determined more generally by personality characteristics. Notably, these characteristics might potentially share associations with dietary disinhibition and being overweight. Therefore, in the final experiment, associations between food-cue reactivity and particular personality characteristics, (impulsivity and sensitivity to reward) were examined.

Prior to conducting the initial experiments, it became evident from the literature that whilst exploring food-cue reactivity in restrained, and disinhibited, eaters it might be important to consider the specificity of this reactivity. *Specificity* literally refers to the extent to which a food cue is only able to elicit an appetite for the cued food. To illustrate this, if after food-cue exposure, appetite for the cued food increases, but appetite for other non-cued foods remains unchanged, then the effects of the food cue can be said to be specific to that food. By contrast, if appetite for a cued food increases along with appetite for non-cued foods, then the effects of food-cue exposure would be considered to be more general in nature. In the initial experiments, evidence for this cue specificity in restrained and disinhibited eaters was considered. Given that this issue appeared to be central to an investigation of food-cue reactivity, in the following experiments it was also considered for the other predictor variables being examined (e.g., everyday portion-size selections, BMI, and personality characteristics).

Notably, in the initial experiments conducted for this thesis, a decision was made to assess associations between everyday dietary behaviour and food-cue reactivity in satiated individuals. This followed Weingarten's (1985) proposals that food cues should elicit a motivational state even in the absence of nutritional need. However, it became evident that this design was limited. This was because, it was impossible to conclude from the findings that the same differences in food-cue reactivity would be evident across the predictor variables (dietary restraint, disinhibition, BMI, impulsivity, and sensitivity to reward) if individuals were tested while they were relatively hungry. For this reason, in the final experiment, individual differences in food-cue reactivity were explored before lunch, while participants were 4-hour food deprived, and immediately after they had eaten to satiety.

To summarise, this thesis explored a series of issues. The first issue relates to associations between food-cue reactivity and everyday dietary behaviour (dietary restraint and dietary disinhibition). The second issue relates to the potential influence of food-cue reactivity in decisions regarding everyday-portion size selections, and for BMI. Finally, the third issue relates to the potential role of particular personality characteristics (impulsivity and sensitivity to reward) in food-cue reactivity. In addition to exploring these three primary issues, the experiments

presented in this thesis also considered two secondary issues. The first of these relates to cue specificity. The second relates to the effect of an individual's motivational state (hungry or satiated) on observed differences in food-cue reactivity. The rationale for considering each of the three main issues and the two secondary issues is presented in the remaining sections of this chapter.

2.6 ISSUE 1: Food-cue reactivity and everyday dietary behaviour

The aim of this section is to provide the rationale for exploring the association between food-cue reactivity and measures of dietary restraint and dietary disinhibition. An historical account of the association between dietary restraint and food-cue reactivity is presented. This begins with a review of literature which prompted speculations that dietary restraint might be an important precedent of externally-motivated eating behaviour. This particular literature dates back to the 1960's and 1970's, and identifies overweight individuals as highly responsive to external cues. Following this, the introduction of the concept of dietary restraint is described, and its relation to external eating behaviour is considered. After reviewing direct evidence associating food-cue reactivity with dietary restraint, the final sub-sections; i) highlight the limitations of the measure used to assess dietary restraint in these studies, and ii) consider the possibility that food-cue reactivity is associated with dietary disinhibition.

2.6.1 Precedents to dietary restraint: The 'externality' hypothesis

Speculation that dietary restraint might share an association with food-cue reactivity resulted from early work relating to externally motivated behaviour in overweight individuals. In the late 1960's and early 1970's Schachter (1968, 1971) proposed that differences in BMI were the key determinant of externally-driven eating behaviour. Specifically, Schachter (1968, 1971) suggested that overweight individuals eat primarily in response to immediate external cues associated with food, and ignore internal physiological stimuli signalling hunger and fullness. By contrast, he suggested that the eating behaviour of normal-weight individuals is

governed primarily by internal physiological signals of energy depletion. These ideas became embodied in Schachter's (1968, 1971) 'externality' hypothesis. Early support for this hypothesis came from a study by Stunkard and Koch (1964). These authors found that stomach contractions and reports of hunger only coincided in normal-weight individuals. In obese individuals, there was little correspondence found between gastric mobility and reports of hunger. A similar finding was also reported by Schachter, Goldman, and Gordan (1968). These authors found that obese individuals consumed similar amounts irrespective of hunger levels. In this study, the authors manipulated hunger state (hungry or satiated) by either asking participants to refrain from eating prior to the onset of the experiment, or by presenting them with a meal of roast beef sandwiches on arrival. In a subsequent taste test, the authors found that obese individuals ate as much, if not slightly more, when they were satiated, compared to when they were food-deprived. In contrast, normal-weight individuals who had recently consumed lunch, ate considerably less than normal-weight participants who were food deprived. These findings were taken as evidence to suggest that obese individuals' eating patterns are characterised by a failure to consider internal physiological need.

Following these initial findings in support of Schachter's (1968, 1971) hypothesis, a large number of studies were conducted which provided further support for his proposals. At least two studies did this by exploring the eating behaviour of overweight, and non-overweight, individuals in their naturalistic settings. In one study reported by Schachter (1971), the food intake of overweight, and non-overweight, college students on weekends and weekdays was observed. The study found that overweight individuals consumed greater amounts on weekdays than weekends. Given that Schachter (1971) suggested that college students' weekday schedule (which is likely to involve on-campus catering) exposes them to a greater number of food cues, he concluded from his findings that overweight individuals are more responsive to external food cues than non-overweight individuals. In another study, Goldman, Jaffa, and Schachter (1968) explored the possibility that in circumstances where external cues are absent, overweight individuals will have an easier time fasting than non-overweight individuals. The authors did this by investigating 24-hour fasting on a Jewish festival. Consistent with their expectations, the authors found that the more time overweight individuals spent in

the synagogue that day away from external food-related cues, the easier they found fasting to be. However, although both these studies are consistent with Schachter's (1968, 1971) externality hypothesis, they were limited because they failed to isolate the effects of external cues on eating behaviour by not experimentally manipulating exposure to these cues.

Unlike the studies reported above, numerous studies have in fact experimentally manipulated exposure to a food cue. In doing this, these studies have reported that various external cues can increase food intake in overweight individuals. For example, the availability of food has been found to be an important determinant of food intake in overweight individuals (Abramson & Stinson, 1977). In a widely cited study, Nisbett (1968a) explored the extent to which the amount of food available affected food consumption in overweight, relative to normal-weight, individuals. To do this, Nisbett (1968a) manipulated availability by presenting participants with either one or three beef sandwiches. He then assessed intake in the two conditions by telling the participants that there were plenty more of these sandwiches in the refrigerator and instructing them to help themselves to as many as they wanted. The findings from this study suggested that overweight individuals who were confronted with three sandwiches ate 57% more than overweight individuals confronted with one sandwich. By contrast, normal-weight individuals were completely unaffected by the experimental conditions, and consumed similar amounts in the one- and three-sandwich conditions. These findings were assumed to result from the fact that three sandwiches provided a more salient cue to the 'external' eater and thereby it was harder for these individuals to resist this food (Nisbett, 1968a).

Other external cues have also been found to be potentially important determinants of food intake in overweight individuals. In several studies, food intake in overweight individuals has been found to be influenced to a greater extent by the accessibility of food, i.e., whether the food is available for immediate consumption. Specifically, overweight adults and children have been found to initiate intake more quickly, and consume greater amounts, of shelled, compared to unshelled, nuts (e.g. Costanzo & Woody, 1979; McArthur & Bustein, 1975; Schachter, 1971; Schachter & Friedman, 1974; Singh & Sikes, 1979). However, this finding is not replicated

when wrapped and unwrapped chocolates are used (Schumaker & Wagner, 1977, Singh & Sikes, 1979). Singh and Sikes (1979) suggested that this discrepancy might result from the fact that individuals are prepared to have to unwrap chocolates because chocolates are typically encountered in wrappers, but they are not prepared to have to unshell nuts

In addition to food availability and food accessibility being cited as important determinants of food intake in overweight individuals, the taste of food, contextual cues such as the time of day, and the salience of a food cue have also been reported to have differential impacts on the eating behaviour of overweight, and non-overweight, individuals. For example, the palatability of food has a greater impact on food consumption for overweight individuals (Decke, 1971, Nisbett 1968b; Price & Grinker, 1973), as does changing the time on a clock to make it appear to be closer to an individual's meal time (Schachter & Gross, 1968). Finally, making a food cue appear more salient (Johnson, 1974; Ross, 1974) also stimulates greater intake in overweight individuals

In light of the amount of evidence taken as support for Schachter's (1968; 1971) model, it is perhaps not surprisingly that his internal/external dichotomy became a widely held framework used to explain differences between normal-weight, and overweight, individuals in the 1960's and 1970's. However, as early as 1981, Rodin suggested that there were many indications that the internal versus external view was too simple a description of differences between weight groups. In support of Rodin's (1981) view, several studies suggested that internal signals alone are also poor regulators of intake in normal-weight individuals as these individuals have also been found to be responsive to external cues (Rodin, 1975b; Schachter & Rodin, 1974; Rodin & Slochower, 1976; Wooley, 1972). In addition to this, after reviewing the available evidence, Leon and Roth (1977) suggested that the evidence for Schachter's (1968, 1971) hypothesis was equivocal at best. This is because a number of studies failed to show reliable overweight/normal weight differences consistently from participant population to participant population, or even from study to study (e.g., Rodin, Moskowitz, & Bray, 1976; Rodin, Slochower, & Fleming; 1977).

Even prior to this criticism of the externality hypothesis, a novel framework for the external/internal distinction was devised by Nisbett (1972). As part of this framework, Nisbett (1972) argued that each person has an individually determined homeostatically defined ideal weight or 'set-point.' This set-point was assumed to be a direct function of the number of fat cells in the body (adipocytes) Nisbett (1972) suggested that, as a result of genetic inheritance and/or overfeeding, obese individuals have higher than average set points because they are over endowed with fat cells. In Nisbett's (1972) view, these individuals can retain this set point, and become seriously overweight, or can strive for a lower body weight thereby suppressing their set points through dieting Nisbett (1972) suggested that it is this biological deprivation caused by dietary restriction, rather than degree of overweight per se, which consequently produces external responsiveness observed in some obese individuals In support of his hypothesis, he pointed out several parallels between obese people and starving organisms. He noted that both groups are more taste-responsive, more emotional, and less active than their normal weight counterparts. Although more recent evidence reviewed in Chapter 1 (Section 1.2) suggests that set points are no longer important determinants of food intake, Nisbett's (1972) speculations are important to consider here because of the implications they have for our understanding of dietary restraint and reactivity to food cues

2.6.2. External eating behaviour and dietary restraint

Nisbett's (1972) observations described in the preceding section were extended by Herman and Mack (1975). These authors suggested that 'dietary restraint' (a tendency to restrict ones dietary intake), rather than body weight per se, might be the critical factor in the 'obese' pattern of eating To explore this possibility, they sought to determine the extent to which more restrained eaters consume a greater amount when attractive food cues are prominent if chronic restraints are experimentally eliminated This was achieved using a 'preloading' paradigm In this paradigm, participants are typically asked to consume a milkshake preload without knowledge of the Kcalorie content of this food, and are then offered *ad-lib.* access to ice-cream in a disguised taste test. It is the preloading phase of the experiment

which is assumed to remove chronic restraints by exceeding the 'permissible' limits on consumption, and subsequently causing normally restrained eaters to abandon their attempt at restriction. The taste test phase subsequently allows experimenters to assess intake in the presence of attractive food cues after these restraints have been removed

In Herman and Mack's (1975) study, participants were asked to consume, one, or two, milkshakes or were offered no milkshake at all (control condition). All participants were then presented with three bowls of ice-cream (chocolate, vanilla, and strawberry) in a disguised taste test. In this taste test, participants were told that they should taste as much of each of the ice-creams as they liked and to rate its taste. They were also told that they could help themselves to any remaining ice-cream after they had made these ratings. In this experiment, the authors believed that this taste test phase would allow them to compare *ad-lib* intake in the presence of attractive food cues in restrained and unrestrained eaters defined according to their scores on the Restraint Scale devised by Herman and Polivy (1980). The eating behaviour of unrestrained participants in this experiment seemed to conform to the pattern formerly thought to characterise all normal weight individuals, namely 'internal' regulation. These individuals consumed smaller amounts after a larger preload (milkshake), than after no preload. In contrast, restrained eaters, although of normal weight, behaved in a manner that Herman and Mack (1975) described as 'external.' This is because they consumed larger amounts of food in the presence of attractive food cues once chronic restraints were removed by ingestion of a preload.

Following Herman and Mack's (1975) study, a series of studies replicated their findings (e.g., Hibscher & Herman, 1977; Ruderman & Christensen, 1983; Ruderman & Wilson, 1979,). However, rather than being interpreted as evidence for 'externality' in restrained eaters, these findings were interpreted as suggesting that restrained eaters 'overeate' after forced consumption of a presumably high energy food because they perceive their diet to be broken. In support of this new interpretation, several studies suggested that restrained eaters' *perception* of 'breaking' their self-imposed Kcalorie confines causes them to overeat. For example, when told that a preload is high in Kcalories, restrained eaters eat somewhat more in a subsequent taste test, than when told the same milkshake is

low-Kcalorie (Polivy, 1976, Spencer & Fremouw, 1979; Woody, Costanzo, Leifer, & Conger, 1981). This new perspective on the eating behaviour of restrained eaters was formalised in Herman and Polivy's (1984) boundary model of dietary restraint. This model suggests that as well as lower hunger boundaries, and higher satiety boundaries, dieters have a third self-imposed 'diet' boundary, marking their maximum desired consumption. Herman and Polivy (1984) suggest that once restrained eaters transgress this diet boundary, the individual can be left feeling that self-control is no longer worth pursuing (the "what the hell" effect, Herman & Polivy, 1984), and consequently eat until they reach the satiety boundary (the 'disinhibition effect').

Despite the fact that preloading studies were no longer interpreted as providing evidence of external eating behaviour in restrained eaters, studies using a more conventional methodology to assess food-cue reactivity have found evidence for greater sensitivity to food cues in restrained eaters. Specifically, apart from a few reports (e.g., Nederkoorn & Jansen, 2002, Overduin, *et al*, 1997), restrained eaters (again defined according to scores obtained on Herman & Polivy's (1980) Restraint Scale) have been found to experience greater physiological responses in the presence of a food cue, to experience a greater urge to eat, and also to consume greater amounts of food. For example, in an early study of this kind, Collins (1978) found that exposure to either pictures of food, or recipes for food, stimulated greater intake in restrained eaters. In contrast, he found little evidence to suggest that eating behaviour was stimulated to a greater extent in these individuals after exposure to a scenery cue. A similar pattern of results was also shown by Rogers and Hill (1989) using olfactory, cognitive, and, visual, food cues. In two separate experiments, the authors found that exposure to the sight and smell of food (some of which was the participants preferred food), and imagining food, stimulated greater *ad-lib* consumption of biscuits in restrained, relative to unrestrained, eaters. In a similar study, using a range of different foods, including cake, smarties, nuts, spiced biscuits, shortbreads, and soft sweets, Jansen and van den Hout (1991) also found that restrained eaters ate significantly more than unrestrained eaters after being asked to hold the food directly under their noses and to concentrate on the smell. More recently, studies have also suggested that restrained eaters consume greater amounts of a cued food when only one food is presented (Fedoroff *et al*, 1997), and

have also suggested that elevated cue reactivity experienced by restrained eaters is cue specific (Fedoroff *et al* , 2003)

In relation to physiological responses to food cues, Nederkoorn, *et al*. (2000) have found that restrained eaters experience greater systolic, and diastolic, blood pressure after being instructed to look at, smell, and imagine eating, three plates of diverse kinds of their preferred foods. Likewise, dietary restriction has also been associated with greater salivation and insulin secretion in response to palatable food cues (Herman, Polivy, & Chhabra, 1981; Herman, Polivy, Klajner, & Esses, 1981, Klajner, Sahakian, Lean, Robbins & James, 1981; LeGoff & Spigelman, 1987; Tepper, 1992, Brunstrom, *et al* , 2004) For example, Klajner, *et al* (1981) found that salivary responses to the sight and smell of pizza and chocolate-chip cookies were significantly greater in restrained, relative to unrestrained, eaters. In the presence of food, salivation increased by only 17% in unrestrained eaters, while in restrained eaters, the authors observed a 56% increase. Similar increases in salivation have also been reported when participants are exposed to low-salience stimuli, such as the smell of palatable food (Herman, *et al* , 1981; LeGoff & Spigelman, 1987), and when participants have recently consumed lunch (Brunstrom *et al.*, 2004).

The reason for restrained eaters heightened reactivity to food cues has been attributed to their attempt to suppress food consumption in the presence of food cues. Indeed, it is assumed that it is this cognitive suppression which in turn elicits desires for food (Fedoroff *et al* , 1997). This conceptualisation of the behaviour of restrained eaters comes from Tiffany's (1990) model of drug urges. In this model, Tiffany (1990) suggests that after a history of drug use, aspects of drug procurement and drug use, become controlled by automatic action schemata. These are similar to the automatic processes described by Shriffrin & Schneider (1977). When an individual is exposed to an 'enabling stimuli' (e g , the sight of a cigarette packet or drug paraphernalia), automatic action schemata are activated and this requires no cognitive effort. However, to abstain from behaviours governed by these automatic action schemata, individuals must recruit non-automatic cognitive processes in an attempt to impede the automatic schemata. Tiffany proposes that it is recruitment of these non-automatic action plans which elicits urges and cravings for the restricted

substance. Extrapolating this model to dietary behaviour, it suggests that in the presence of a food-related cue, automatic action plans are activated and individuals eat. However, for restrained eaters who are attempting to abstain from eating, non-automatic cognitive resources must be drawn upon to impede these automatic eating action plans which in turn will elicit craving for this food

Taken together, the studies reviewed here provide compelling empirical and theoretical support for the notion that food-cue reactivity is elevated in restrained eaters. However, it is important to note that dietary restraint has been assessed in these empirical studies using Herman and Polivy's (1980) Restraint Scale. Although this scale has become the most widely used measure of dietary restraint, its construct validity has been questioned on several occasions. This is because it has been found to measure at least two separate constructs; concern for dieting and weight fluctuation/disinhibited eating (Blanchard & Frost, 1983; Drewnowski, Risky, & Desor, 1982; Heatherton, Herman, Polivy, King & McGree, 1988; Johnson, Lake, & Mahan, 1983; Lowe, 1984; Laessle, Tuschl, Kotthaus, Pirke, 1989). This is problematic because dietary restraint is not a unitary concept and restrained eaters may/or may not engage in disinhibited eating and experience weight fluctuation. Other questionnaires, such as the Dutch Eating Behaviour Questionnaire (DEBQ, van Strien, Frijters, Bergers, & Defares 1986) and Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985), recognise this and measure dietary restraint independently of dietary disinhibition.

Given that food-cue reactivity has only previously been associated with the Restraint Scale and this scale conflates dietary restraint with disinhibition, one possibility is that food-cue reactivity is not associated with dietary restraint independently of dietary disinhibition or weight fluctuation. Relevant to this, several recent studies have suggested that other instances of overeating (e.g., after consumption of a preload, and after exposure to a stressor) which are associated with the Restraint Scale, are not associated with independent measures of dietary restraint (Dritschel, Cooper, & Charnock, 1993; Steere & Cooper, 1993; Jansen, Vandenburg, & Bulten, 1992; Lowe & Kleifield, 1988,). The reason for this is likely to be that, unlike the Restraint Scale (Herman & Polivy, 1980), these independent measures do not select individuals based on their predisposition to

'disinhibit' (Haynes, Lee, & Yeomans, 2003). Indeed, using questionnaires that offer separate measures of disinhibition and dietary restraint [e.g., DEBQ (van Strien, Frijters, Bergers, & Defares 1986) and TFEQ (Stunkard & Messick, 1985)], recent studies have suggested that only individuals with simultaneously high restraint, and disinhibition, scores overeat in the presence of external triggers (i.e., preloads, stressors, and palatable tastes) (Haynes *et al.*, 2003; Ouwens, van Strien, & van der Stark, 2003, van Strien, Cleven, & Shippers, 2000, Westenhoefer, Broeckmann, Munch, & Pudel, 1994, Yeomans, Tovey, Tinley, & Haynes, 2004). Given this, the need to explore associations between food-cue reactivity and independent measures of dietary restraint and dietary disinhibition is imminent. One possibility is that reactivity to food cues might be associated with dietary disinhibition, rather than a pure measure of dietary restraint.

In Experiments 1 and 2, separate measures of restraint and dietary disinhibition were employed to explore this possibility. The Dutch Eating Behaviour Questionnaire (DEBQ; van Strien, Frijters, Bergers, & Defares 1986) was chosen as an independent measure of dietary restraint. Unlike Herman and Polivy's Restraint Scale, this scale has been found to measure intention to restrict, and actual restriction of food intake (Leselle, *et al.*, 1989). For example, Wardle and Beales (1987) found that restrained eaters identified using the restraint scale of the DEBQ report consuming 300kcal a day fewer than unrestrained eaters. Likewise, Leselle *et al.* (1989) found that mean daily caloric intake estimated by means of a 7-day food diary was negatively correlated with this restraint scale. Finally, high scores on this scale have been associated with lower scores on various overeating scales (van Strien, 1997), and are relatively less associated with being overweight than the Restraint Scale (Ridgeway & Jeffrey, 1998). Dietary disinhibition was assessed in these experiments using the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985) disinhibition scale. The scale was constructed using items from two existing questionnaires, the Restraint Scale, and the Latent Obesity Questionnaire (Pudel, Metzendorff, & Oetting, 1975), and from newly written items based on the authors' clinical experience of eating behaviour. This scale measures behavioural and weight liability, and reflects a more general dimension of disinhibited eating.

2.7 ISSUE 2: Food-cue reactivity, BMI, and everyday portion-size selection

The possibility that dietary disinhibition might be associated with food-cue reactivity has direct implications for considering other variables which might be important to food-cue reactivity. Notably, dietary disinhibition has been associated with the consumption of larger everyday portion sizes (Brunstrom, Mitchell, & Baguley, 2005), and higher BMI's (Bellisle, Clement, la Barzic, Le Gall, Guy-Grand, & Basdevant, 2004, Lindroos, Lissner, Mathiassen, Karlsson, Sullivan, Bengtsson, & Sjostrom, 1997). Therefore, it is perhaps possible that food-cue reactivity might also be associated with being overweight and greater everyday food consumption

Several studies have suggested that exposure to a food cue can increase the amount of food that is subsequently ingested (see Part I, section 2.3). Thus, if, as would be expected, those individuals who are highly reactive to food cues in the laboratory are also highly sensitive to these cues outside the laboratory, it follows that they are likely to overeat whenever such cues are encountered. Over time, in the absence of increased energy expenditure, this 'overeating' is likely to result in a positive energy balance. This in turn is likely to accumulate in weight gain. Given this, a possibility worthy of consideration is the extent to which individuals who show elevated sensitivity to food cues in the laboratory consume larger amounts of food within their everyday lives, and are more likely to be overweight.

In the preceding section (2.6) evidence was reviewed which suggested that obese individuals might have greater sensitivity to environmental cues associated with food intake. However, as explained above, this externally-driven behaviour was later attributed to dietary restraint. Given that it has been hypothesised here that food-cue reactivity might *not* be a result of dietary restriction, this constitutes another important reason for reconsidering associations between being overweight and reactivity to external food cues. Recently, Jansen, Theunissen, Slechten, Nederkoorn, Boon, Mulken *et al* (2003) have reported greater sensitivity to food

cues in overweight children. However, despite this, there have been no recent demonstrations of greater food-cue reactivity in overweight adults.

In light of the evidence reviewed here, later experiments presented in this thesis considered the potential role of food-cue reactivity in everyday food consumption, and explored the implications of being overweight for sensitivity to food cues. Experiments 3, 4, and 5 explored the association between food-cue reactivity and everyday-portion size selections, while Experiment 5 considered the association with being overweight.

2.8 ISSUE 3: Potential role of personality characteristics in food-cue reactivity

If, food-cue reactivity is associated with being overweight, it might be important to begin to understand what it is about an overweight individual that causes this greater reactivity. One possibility is that some aspect of their personality renders them more susceptible to the stimulatory effects of food cues than non-overweight individuals. Based on evidence to date, it can be speculated that particular personality characteristics which might share an association with food-cue reactivity are impulsivity and sensitivity to reward. Given that these characteristics are expressed to a greater extent in obese, relative to non-obese individuals (Franken & Muris, 2005; Nederkooij, Braet, Van Eijs, Tanghe, & Jansen, in press; Nederkooij, Smulders, Havermans, Roefs, & Jansen, 2006), one possibility is that they are in fact influential variables in determining levels of food-cue reactivity. In this section, evidence for an association between food-cue reactivity and these personality characteristics will be considered. The first subsection assesses evidence for a role of sensitivity to reward in food-cue reactivity. This begins with an historical review of the origins of the sensitivity to reward trait. The following subsection introduces the notion of impulsivity and provides evidence for its potential involvement in food-cue reactivity.

2.8.1 Potential role of the BAS in food-cue reactivity

Temperament is an aspect of personality that may be determined genetically and therefore could be biologically based. A very popular model of temperament was formulated by Eysenck (1957, 1967). He proposed that there are two main dimensions of temperament: neuroticism/stability and extraversion/introversion. Thus, individuals lie at a particular point on the extraversion/introversion continuum *and* at a particular point on the neuroticism/stability continuum. For example, one individual might be extraverted and neurotic, while another individual might be extraverted yet stable. According to Eysenck (1957, 1967), extraverts and introverts differ in the sensitivity of their cortical arousal system. Extraverts have low cortical

arousal and are therefore in need of external stimulation. In contrast to this, introverts have higher cortical arousal and are therefore over-aroused. Eysenck's second dimension, neuroticism, is based on activation thresholds in the sympathetic nervous system or visceral brain. Neuroticism, or emotionality as he referred to it, is characterized by high levels of negative affect such as depression and anxiety. The direct opposite of neuroticism was regarded by Eysenck as 'stable.' Individuals with this temperament, according to Eysenck were emotionally stable people who have high activation thresholds and good emotional control.

As part of his proposals of temperament, Eysenck's described the behaviour of an introvert as 'over-socialised,' and the behaviour of an extrovert as 'under-socialised.' He suggested that the process of socialisation involves a cluster of feared conditioned reactions. In determining why introverts form stronger conditioned fear reactions he suggested that it is because they are better at conditioning (Eysenck, 1965, 1966). However, in a discussion on this aspect of Eysenck's theory, Gray (1970) hypothesised that it is in fact because they are more susceptible to fear. More specifically, Gray (1970) was suggesting that introverts have a heightened sensitivity to punishment or to warnings of punishment. Following from this, he suggested that in contrast, the behaviour of extraverts is determined by potential rewards and is influenced to a lesser extent by the proposition of punishment. Consistent with Gray's formulation, extraverts have been found to condition best under rewarding conditions in instrumental tasks (e.g., Gupta, 1996; Gupta & Nagpal, 1978; Gupta & Shukla, 1989; Nagpal & Gupta, 1979), and in more general performance tasks such as computer games, and calculations with recoded numbers (e.g., Boddy, Carver, & Rowley, 1986). For Gray (1970), Eysenck's notion of neuroticism reflects the degree of sensitivity to punishment and reward. Thus, neurotics are likely to be more susceptible to both punishment and reward. In contrast, those who fall on the opposite end of this dimension, i.e., stable, are likely to be less susceptible to either of these sensitivities.

Following from his early writing, Gray (1976; 1981, 1987a, 1987b) formalised his ideas in what has become known as the Reinforcement Sensitivity Theory (STR). Not surprisingly, he suggested that two motivational systems underlie behaviour and affect. He refers to these two systems as a Behavioural Inhibition System (BIS)

and a Behavioural Approach System (BAS) These two systems reflect individual differences in the sensitivity of two neurological systems in their responses to relevant motivational cues. The BIS inhibits behaviour in the presence of cues signalling that aversive consequences will follow should a certain response be made. It is therefore assumed to reflect the personality dimension of anxiety. The BAS is thought to be a reward, or approach², system that responds to positive incentives by activating behaviour and is assumed to reflect the personality dimension of sensitivity to reward. The BAS continuously monitors the environment for signals of reward. When a cue associated with reward is encountered, the BAS is presumably activated through activation of the dopaminergic system (Gray, 1987b), and motor output is then increased towards the reward, further activating the BAS and promoting approach behaviour (Kane, Loxton, Staiger, & Dawe, 2004)

Notably, a higher BAS-trait has been associated with traffic violations (Castella & Perez, 2004), finding action and adventure films more interesting (Aluja-Fabregat & Torrubia, 1998), and having higher sexual excitatory and satisfaction levels (Aluja, 2004). Furthermore it has also been associated with alcohol use/abuse (e.g., Christensen, Henderson, Jacomb, Korten, Rodgers, 1999; Cloninger, Sigvardsson, & Bohman, 1988; Howard, Kivlahan & Walker, 1997; Jorm, Loxton & Dawe, 2001; O'Conner & Colder, 2005), a tendency to smoke (Howard, *et al*, 1997), and more generally with substance abuse (Knyazeu, 2004; Knyazeu, Slobodskaya, Kharchenko, & Wilson, 2004; Masse & Tremblay, 1997;). The reason that a high BAS-related trait is associated with these behaviours is likely to reflect the fact that the BAS activates behaviours which are associated with the delivery of a reward, such as alcohol use. Thus, it might be hypothesised that a hypersensitivity to reward might be the common vulnerability for all these behaviours.

In addition to responding to primary rewards, such as alcohol, the BAS is also assumed to respond to previously neutral cues which have become *associated* with a reward. In a relatively recent study, Franken (2002) sought to determine the extent

² An approach system is one which motivates behaviour to obtain a reward associated with a particular stimulus

to which greater BAS activity is associated with reactivity to cues associated with alcohol use. To do this, 58 participants were recruited from an inpatient alcoholism treatment program, and from the general population. BAS activation was determined by scores obtained on Carver and White's (1994) BAS scale which comprises of a drive, reward sensitivity, and a fun seeking, subscale. Alcohol reactivity in turn was determined by exposing participants to 10 different photographs of alcoholic beverages presented on a computer screen four times, and then assessing appetitive motivation. Consistent with the author's expectations, those individuals who obtained higher scores on the BAS-Drive subscale reported stronger desires and intentions to drink. Likewise, those who obtained higher scores on the BAS-reward sensitivity scale experienced greater negative reinforcement craving, which reflects the expected relief from negative states through drinking alcohol. However, one limitation of this study was that it did not include a control condition (i.e., a no-cue condition). Therefore, it is unclear whether the relationships observed between the BAS subscales and desires and craving for alcohol were in fact a result of exposure to the alcohol cues.

However, in a previous study conducted by Kambouropoulos and Staiger (2001) this problem was addressed by adopting two cues; a neutral cue (a glass of water) and an alcohol cue (a glass of beer). Participants (38 heavy and light drinkers) were exposed initially to the neutral cue and then to the alcohol cue for three minutes. During this exposure phase they were asked to take a sip of each drink. The extent to which those individuals who showed greater reactivity to the alcohol cue also had a high BAS-related trait was assessed by calculating the effect of the alcohol cue on appetitive motivation and then by determining the extent to which this was related to BAS activity as defined by Carver and White's (1994) BAS scales. As well as exploring this association between BAS sensitivity and cue reactivity, Kambouropoulos and Staiger (2001) also moved a step backwards by determining the extent to which the BAS is activated after exposure to an alcohol cue. To do this, the authors explored reactivity of the BAS after exposure to the neutral cue, and then after exposure to the alcohol cue. BAS was assessed in this instance using the CARROT task (Powell, Al-Adawi, Morgan, & Greenwood, 1996). This measures the increase in speed on a card-sorting task in response to a small financial reward. Consistent with Gray's conceptualisation of the BAS, the authors found that

performance on the CARROT task was significantly greater after exposure to the alcohol cue than after exposure to the neutral cue. This suggests that the BAS was activated in response to conditioned alcohol cues. Since greater performance on the CARROT task after exposure to the alcohol cue was only observed in heavy drinkers, it also suggested that it is only these individuals who experienced greater BAS activation in the presence of alcohol-related cues. This is perhaps not surprising in light of the finding that it was also only these individuals who experienced a greater urge to drink after exposure to the alcohol, relative to the neutral, cues. Following from this, the authors also found that those individuals who typically have a high BAS-related trait were found to experience a greater urge to drink in the presence of alcohol, relative to being in the presence of the neutral cue. In a subsequent study, Kambouropoulos and Staiger (2004) replicated this latter finding by also suggesting that reactivity to an alcohol cue (i.e., drinking alcohol) was significantly associated with a measure of BAS sensitivity.

Therefore, taken together, the studies conducted by Kambouropoulos and Staiger (2001, 2004) appear to provide evidence to support 1) the contention that the BAS is activated during exposure to an alcohol relative to a neutral cue, and 11) that heightened sensitivity of the BAS is associated with greater reactivity to alcohol cues. Thus, it follows from these findings that other forms of cue reactivity, such as food-cue reactivity, might also be experienced to a greater extent in individuals with a highly reactive BAS. Therefore, the final experiment (Experiment 6) presented in this thesis explored associations between food-cue reactivity and the BAS-related trait.

2.8.2 Food-cue reactivity and impulsivity

Previously in this review (see section 2.6 2), it has been hypothesised that food-cue reactivity might be associated with dietary disinhibition. This dietary behaviour can be conceptualised as a susceptibility to eat in the presence of external triggers, such as particular social situations, emotional cues, and external food cues. One possibility is that as well as being associated with this specific deficit in dietary control, food-cue reactivity might also be associated with a more general inability to

inhibit responses to cues which offer a reward. In other words, it might also be associated with an impulsive personality trait. Indeed, it is conceivable that in the presence of a palatable food cue, impulsive individuals might be unable to resist the temptation to eat offered by this cue. This issue is worthy of consideration because it might aid in the development of our understanding of the fundamental processes governing some aspects of overeating.

Importantly, impulsivity has been associated with various behaviours which are assumed to offer some form of temptation. Specifically, it has been associated with a tendency to smoke (Doran, Spring, McChargue, Pergadia, & Richmond, 2004, Grano, Virtane, Vahtera, Elovainio, & Kivimäki, 2004; Mitchell, 1999;), alcohol consumption (Grau & Ortet, 1999; Grano *et al.*, 2004, Waldeck & Miller, 1997;), methamphetamine use (Simons, Oliver, Gaher, Ebel, & Brummels, 2005), and binge eating (Claes, Vandereycken, & Vertommen, 2002; Nasser, Gluck & Geliebter, 2004). Given this, it might be concluded that impulsivity does reflect an inability to resist temptation. Thus, given that exposure to a food cue offers a tempting invitation to eat, it is likely that impulsivity is also associated with greater intake after food-cue exposure. However, despite the feasibility of this possibility, to date, it has not been considered empirically.

One possibility which has been considered, however, is the extent to which food-cue exposure *reduces* the ability to inhibit impulses to act. Nederkorn, Eijs, and Jansen (2004) explored this possibility in individuals already presumed to be highly reactivity to food cues (i.e., restrained eaters defined according to the Herman & Polivy's Restraint Scale). The authors used the stop/start signal task to measure inability to inhibit responses. This task involves two concurrent tasks, a 'go' task which is a choice reaction time task and a 'stop' signal which informs participants to inhibit their response to the 'go' task. The participants in this study were asked to complete this task in the absence of cue exposure and after two exposure phases. In these exposure phases, participants were presented with a variety of chocolates and crisps. Initially, they were asked to select their favourite chocolate and their favourite crisps. After this, they were requested to smell the food and to taste a small piece of it. However, despite their attempt, the authors reported little evidence to suggest that inhibitory control decreased after food-cue exposure in individuals

who have previously been found to experience greater cue reactivity (i.e., restrained eaters) This suggests that deficits in general inhibitory control do not *increase* as a result of food-cue exposure

However, despite the fact that food-cue exposure does not *increase* deficits in inhibitory control, it remains possible that individuals who are typically more impulsive are *generally* more reactive to the food cues than less impulsive individuals For this reason, the final experiment presented in this thesis (Experiment 6) also assesses associations between food-cue reactivity and measures of impulsivity.

2.9 SECONDARY ISSUE 1: Cue specificity

A potentially interesting question in relation to food-cue reactivity is the extent to which exposure to a food cue elicits an *exclusive* appetite for the cued food, rather than an indiscriminate appetite for food. This possibility was originally considered by Weingarten and his colleagues (Weingarten, 1985; Weingarten & Elston, 1990) and has lead to suggestions that the motivation elicited by an environmental food cue is in fact *specific* to the food which has been cued. By this, these authors mean that priming participants with pizza, for example, would stimulate appetite for this food, but would not stimulate appetite for another food, such as cookies.

This notion of specific cued responses is consistent in some respects with similar suggestions made in reference to other aspects of eating behaviour, such as meal termination. Indeed, it is now well-established that satiety experienced after eating is specific to the sensory characteristics of the eaten food. This phenomenon has been referred to as sensory-specific satiety (SSS) and broadly suggests that meal termination is the result of a decline in pleasantness of the sensory characteristics of an eaten food (Guinard & Brun, 1998; Rolls & Rolls, 1997, Rolls, Rolls, & Rowe, 1983; Rolls, Rowe, Rolls, Kingson, & Megson, 1981). Put simply, SSS suggests that as we eat a food the pleasantness of the taste, smell, and texture, of that food, but not others, declines Consequently, we might terminate intake of one food, but

are more than happy to initiate intake of a new food with different sensory properties. Therefore, taken together, this notion of SSS and Weingarten's notion of specific learned appetites suggests that both meal initiation and meal termination might incorporate these food-specific components.

Whilst there is a large body of evidence for food-specific meal termination, evidence for cue-specific meal initiation is relatively scarce. In fact, evidence of cue-specific reactivity has come largely from Weingarten's unpublished work (Weingarten 1984, Unpublished data reported in Weingarten, 1984). From this unpublished data Weingarten reported that when conditioned stimuli (CS) for a food is presented, animals wait for the expected food to be delivered, even if food is continuously available in another place in the cage. This suggests that the stimulus does not elicit a general appetite for food, but rather a specific appetite for the food that is expected after presentation of the CS. In a similar way, other studies which Weingarten uses to justify his cue specificity suggest that animals who have learned to bar press for food continue to perform the instrumental response even when food is made freely available in the test situation (Osbourne, 1977; Neuringer, 1969).

In humans, the extent to which food-cue exposure stimulates a specific motivation to eat the cued food has been explored by Cornell, Rodin, and Weingarten (1989). In this study, the authors exposed satiated participants to either ice-cream, pizza, or to the same environment in the absence of food-cue exposure (no-cue condition). Following this, all participants were given *ad-lib* access to both ice cream and pizza. The authors were then able to compare *ad-lib* intake of the cued food relative to *ad-lib* intake of the non-cued food. Doing this, they provided evidence to suggest that the effects of cue exposure are specific to the cued food.

Given this evidence for cue-specific reactivity, one possibility is that if there are individual differences in the extent to which a food-cue can motivate eating behaviour, these differences in motivation to eat will be specific to the cued food. Recently, Fedoroff, *et al* (2003) explored the extent to which cue-elicited motivation to eat in restrained eaters (defined according to their scores on the Restraint Scale) was specific to the cued food. In this study, 132 food-deprived (two

hours food-deprived) restrained, and unrestrained, eaters were exposed to the smell of either pizza, cookies, or to no smell, for 10 minutes. During this time, they were asked to write their thoughts (corresponding to the olfactory cue) about pizza, or cookies, or to record their thoughts in general. After cue exposure, all participants rated their subjective appetite for both pizza, and cookies, and were offered *ad-lib* access to these foods. The authors then compared subjective appetite for cookies and pizza, and intake of these two foods, separately, across the three conditions (pizza-cue, cookie-cue, no-cue), and determined the extent to which it interacted with restraint status. In doing this, the authors found that restrained eaters consumed larger amounts of pizza and cookies after exposure to these foods than unrestrained eaters. Furthermore, motivation to eat both these foods was greater in restrained relative to unrestrained eaters *only* after exposure to the cue associated with that specific food. When that food had *not* been cued, restrained eaters in fact consumed smaller amounts than unrestrained eaters. Restrained eaters also craved cookies to a greater extent than restrained eaters *only* after being primed with this food. However, craving for pizza in this study surprisingly did not differ across restrained and unrestrained eaters after cue exposure

As stated previously, the measure of restraint used in food-cue reactivity studies, such as that described above by Fedoroff *et al* (2003), is also associated with weight fluctuation and disinhibited eating (see section 2.6.2). For this reason, in the experiments presented in this thesis, separate measures of restraint and disinhibition were used to differentiate between the roles of these two dietary behaviours in cue reactivity (see section 2.6.2). Since the preceding discussion suggests that the Restraint Scale (Herman & Polivy, 1980) predicts a cue-specific response, it follows that an assessment of the associations between food-cue reactivity and separate measures of dietary restraint and disinhibition should also explore cue specificity. Thus, the aim of Experiments 1 and 2 was to assess food-cue reactivity across separate measures of restraint and disinhibition, and to determine the extent to which any greater reactivity observed in restrained, or disinhibited, eaters is specific to the cued food. Where possible in the remaining experiments, cue specificity was also explored in relation to the other predictor variables considered (e.g., everyday portion-size selection, BMI, sensitivity to reward, and impulsivity). This was because cue specificity appears to be fundamental to our understanding of food-cue

reactivity

2.10 SECONDARY ISSUE 2: Role of motivational state

After a series of experiments which explored individual differences in food-cue reactivity in satiated participants, in the final experiment presented in this thesis it was also useful to assess these individual differences in the absence of satiety. Notably, the notion that the levels of hunger and satiety might determine the extent to which a conditioned stimulus (e.g., a food cue) is able to elicit a conditioned response (e.g., eating behaviour) has been considered in a number of general scientific theories of learned motivated behaviours

The drive reduction theories reviewed in Chapter 1 (section 1.4.2) suggest that conditioned stimuli motivate behaviour because they are associated with a reduction in a particular drive. Thus, according to this perspective, food cues motivate eating behaviour because they are associated with a reduction in hunger drive. By implication, therefore, according to this theory, food cues will only stimulate eating behaviour in the presence of a motivational drive to eat.

Contrary to the drive reduction theory, motivational state has not been *integral* in other theories of externally-cued behaviour. However, despite this, several authors have speculated as to how it might be involved. For example, Bindra (1974) who suggests that the CS gains incentive motivation and thereby motivates behaviour (incentive motivation theory; section 1.4.3) has suggested that these stimuli would only elicit this motivational arousal when the 'organismic state was appropriate' i.e., when internal physiological factors were conducive. Toates (1981) elaborated on Bindra's (1974) view by proposing that 'internal state' can encourage or restrain responding to stimuli which have gained incentive motivation, suggesting that a response to an incentive stimuli is determined by the interaction between internal motivational state and the incentive value assigned to the stimulus. In a similar way, Davidson (1993) in his theorising relating to goal-directed behaviour and motivational state suggested that physiological deprivation (such as food deprivation) acts as a modulator of the relationship between external environmental

stimuli (e.g., sight and smell of food) and unconditioned stimuli (e.g., reward value of food). In this way, food deprivation can strengthen this relationship increasing the probability of the environmental cue eliciting a conditioned response. In contrast, in the absence of food deprivation, environmental cues alone cannot elicit this conditioned response. According to Davidson (1993), this is because the modulator determines the extent to which the US (Unconditioned Stimulus) memory requires activation. Thus, in states of extreme food deprivation, the threshold required for US memory activation will be low, while in the absence of these states this threshold will be high. Similar to Davidson's (1993) modulators are 'establishing operations (EO)' discussed by Tapper (2005). These have also been termed 'motivating operations (MO)' and were originally devised by Michael (1982, 1993, 2000). They refer essentially to stimulus condition, or to environmental stimuli which have become associated with this condition. Interestingly, EO's increase the reinforcing, or punishing, ability of events and encourage behaviours associated with this event. For example, food deprivation might act as an EO, thereby encouraging the reinforcing value of food, and stimulating food intake. Most relevant to the current discussion is the fact that these operations might also affect the extent to which environmental stimuli are able to motivate behaviour. For example, like Davidson's (1993) modulator, these operations might *encourage* or *discourage* responses to environmental stimuli which predict a reward associated with the particular EO.

Coons and White (1977) presented a mathematical model of the interaction between motivational state and the effect of external stimuli on behaviour. Similar to the theories described above, this model suggests that energy state determines the current value of conditioned incentive stimuli. However, this model also proposed that internal motivational states can *determine* the incentive value that is assigned to a particular stimulus during conditioning. For example, in some motivational states (e.g., when food deprived) an incentive (e.g., food) will be rewarding and thereby stimuli which preceded the occurrence of this reward (e.g., food cues) will gain incentive motivation. By contrast, in some motivational states (e.g., when satiated) an incentive might not be rewarding and therefore stimuli which preceded its occurrence will not be granted incentive motivation.

This notion that internal motivational drive can *determine* the incentive value assigned to neutral stimuli during conditioning is supported by research and theorising by Dickinson and his colleagues (Dickinson & Balleine, 1994, 2002). Consistent with Coons and White (1977), these authors suggest that previous experience of an outcome in a particular motivational state determines its incentive value, a process they call 'incentive learning.' Thus, according to these authors the motivation aroused by an incentive stimulus is contingent upon the extent to which it was perceived as rewarding when it was previously experienced in the current motivational state. For example, the incentive value of an ice-cream offered to a child in exchange for doing a simple task, such as cleaning their room, or taking the dog for a walk, would be determined by the child's previous experience with ice-cream. If the ice-cream was previously found to be rewarding when consumed in the current motivational state, it will have a high incentive value and will therefore encourage the child to engage in the task. In contrast, if it was not previously found to be rewarding in the current motivation state the child is unlikely to engage in the current task, as the reward provides little incentive motivation.

Evidence for incentive learning came largely from Balleine's (1992) study on rats. In this study, Balleine (1992) examined the effects of shifts in motivational state from training to test phases using unfamiliar foods, such as the standard high protein Noyes rewards pellets or a poly-saccharine (maltrodextrin) solution, as the outcome. Initially, Balleine (1992) found that when food-deprived rats were trained to press the lever for these outcomes, and then shifted to a non-deprived state in the test phase, the rats would continue to press the lever for the food and starch solution. This is because the outcome had been assigned a high incentive value in the training phase when it was encountered while food-deprived. Indeed, Balleine (1992) found that the rats only reduced lever presses while non-deprived in a test phase if they had previously encountered the outcomes while non-food deprived. This is because during training they had been able to assign the outcome a low incentive value because they were non-food deprived.

Further support for the concept of incentive learning in Balleine's (1992) study was found when non-deprived rats were taught that one action (lever-pressing or chain pulling) produced one outcome (Noyes pellets or the starch solution), and that the

alternative action produced the alternative outcome. Prior to this training, all animals had received access to one of the outcomes when non-food deprived and the other when food-deprived. When the animals were given the choice between the two alternatives when hungry they showed reliable preference for the action associated during training with the outcome that had been pre-exposed while hungry.

Balleine's (1992) study is not alone in yielding support for an incentive learning model of instrumental responding. For example, several other studies have shown that a reduction in the level of food deprivation has no detectable effect on test performance unless the animals receive prior experience with the food pellets in the non-deprived state (Balleine & Dickinson, 1994; Corbit & Balleine, 2003; Dickinson, Balleine, Watt, Gonzalez, & Boakes, 1995). Likewise, a number of studies have found that non-deprived animals continue to bar press for food, or drink, when they have previously experienced this outcome when hungry (Capaldi, Davidson, & Myers, 1981; Lopez, Balleine, & Dickinson, 1992; Revusky, 1967, 1968). Finally, some studies have found that devaluing a particular substance by pairing it with an aversive stimuli, or allowing animals to experience it after being satiated on this food, can reduce the action originally associated with this outcome, but does not reduce actions associated with different food outcomes (Balleine & Dickinson, 1998; Rescorla, 1990).

Taken together, the theories reviewed here provide support for the contention that motivational state might play an important role in externally-cued motivated behaviour. Thus, given that throughout this thesis associations between food-cue reactivity and the various predictor variables (e.g., dietary restraint, dietary disinhibition, everyday portion-size selection, and being overweight) were assessed while individuals were satiated, it was also important to consider these associations in the absence of satiety. Therefore, the final experiment explored these associations when individuals were relatively hungry (i.e., after four hours food deprivation) and after they had eaten to satiety.

2.11 Summary and thesis overview

This thesis considers individual differences in food-cue reactivity. Specifically, Experiments 1 and 2 explore relationships between food-cue reactivity and separate measures of dietary restraint and disinhibition (Issue 1). The following experiments assess the extent to which food-cue reactivity is elevated in individuals who typically select larger everyday portion sizes (Experiments 3, 4, and 5), and those who are overweight (Experiment 5) (Issue 2). The primary aim of the final experiment is to explore evidence for an association between food-cue reactivity and particular personality variables (impulsivity and sensitivity to reward) (Issue 3). As a secondary issue, this final experiment also considers individual differences in food-cue reactivity when participants are relatively hungry (i.e., after four hours food deprivation), and after they have eaten to satiety (Secondary issue 2).

In the initial experiments (Experiments 1 and 2) evidence for cue specificity in restrained and disinhibited eaters is also considered (Secondary issue 1). Following this, in the subsequent experiments, specificity is explored in relation to each of the characteristics previously considered (e.g., everyday portion-size selection, being overweight, impulsivity, and sensitivity to reward).

CHAPTER 3

FOOD-SPECIFIC REACTIVITY AND EVERYDAY DIETARY BEHAVIOUR

3.1 Chapter Overview

This chapter presents the methods and findings from Experiment 1 (Part I) and Experiment 2 (Part II). The aim of both these experiments was to assess associations between food-cue reactivity and separate measures of dietary restraint and disinhibition. As part of this, each of the experiments explored the extent to which these separate measures of dietary behaviour were associated with an exclusive motivation to eat the cued food (cue specificity). In Experiment 1, cue specificity was assessed by comparing subjective appetite (desire-to-eat, and craving) for the cued food (pizza) with subjective appetite for two non-cued foods (chips and cookies). In Experiment 2, a more sophisticated method was employed. This involved comparing *ad-lib* intake of a cued food (chips or pizza), with *ad-lib* intake of a non-cued food (chips or pizza).

PART I: EXPERIMENT 1

3.2 Introduction

Previous studies have reported that the effects of food-cue exposure are especially pronounced in restrained eaters (e.g., Fedoroff, *et al*, 1997; Fedoroff *et al*, 2003; Rogers & Hill, 1989). However, these studies have tended to use the Restraint Scale devised by Herman & Polivy (1980), and unlike other measures of restraint, this scale is also associated with weight fluctuation and disinhibited eating. Given this,

one possibility is that food-cue reactivity might in fact be more closely associated with dietary disinhibition. To address this issue, Experiment 1 explored associations between food-cue reactivity and separate measures of dietary restraint (DEBQ-R) and disinhibition (TFEQ-D)³. It was hypothesised that those individuals with high disinhibition scores would experience greater cue reactivity than those individuals with lower disinhibition scores. By contrast, it was expected that restrained eaters would not experience any greater cue reactivity than unrestrained eaters

As part of this experiment, it was desirable to determine the extent to which any greater cue reactivity observed across individuals with specific dietary behaviours were *specific* to the cued food. Previously, Fedoroff *et al* (2003) have explored the specificity of food-cue reactivity in restrained eaters defined according to their scores on Herman and Polivy's Restraint Scale. The authors found that restrained eaters experience a greater appetite for the cued food than unrestrained eaters. However, their appetite for a food which had not been cued did not differ significantly to that experienced by unrestrained eaters. Given this, in this experiment, it was expected that if individuals with higher disinhibition scores experience a greater motivation to eat after food-cue exposure than individuals with lower disinhibition scores, this differential motivation to eat will be exclusive to the cued food. Put simply, the change in appetite brought about by exposure to a food cue might be greater for the cued food in individuals with high, relative to low, disinhibition scores, but is unlikely to differ for the non-cued foods. Contrary to this, it was expected that restrained eaters appetite for the cued, and non-cued, foods would not differ after cue exposure to that experienced by restrained eaters.

In Fedoroff *et al* 's study (2003), specificity was explored by exposing participants to either cookies, pizza, or to the same environment in the absence of either of these foods, and then by assessing their motivation to eat both pizza and cookies. Fedoroff *et al* (2003) suggested that if food-cue reactivity reflects a food-specific

³ The DEBQ-R was used in this experiment rather than the TFEQ-R because it was consistent with the measures used by the research group within the Ingestive Behaviour laboratory at Loughborough University. Therefore, using this scale ensured that the results were comparable across the research group. Notably, initial analyses suggested that the results did not differ when the TFEQ-R was used as a measure of dietary restraint in this experiment

response, then motivation-to-eat a particular food will be greater *only* after cueing with that specific food. It will thereby be unaffected by pre-exposure to a different food. To explore this possibility, the authors compared subjective appetite and intake of the two test foods (pizza and cookies) after being cued with this food, after being cued with the other test food, and in the absence of prior cue exposure. The authors expected that motivation to eat the test food would be greater than in the absence of cue exposure after cueing with that particular food, but not after cueing with another food. Thus, for Fedoroff *et al.* (2003) using the no-cue condition as a reference group, appetite for cookies would only be elevated after exposure to this food. After exposure to pizza, appetite for cookies would be similar to that observed in the absence of cue exposure, i.e., in the no-cue condition. In a similar way, appetite for pizza would only be elevated with respect to the no-cue condition after cueing with this food. Using this methodology, the authors were able to consider the effect of cue exposure on appetite for the cued food and for other non-cued foods across scores on the Restraint Scale.

In the present experiment a methodology akin to that used by Fedoroff *et al.* (2003) was adopted to explore specificity across restraint and disinhibition scores. However, there were several differences. Firstly, in this experiment, specificity was only assessed for subjective appetite ratings. This was because only a measure of *ad-lib* intake of the cued food (pizza) was obtained in this experiment. The reason for this was that this experiment constituted a first attempt to explore food-cue reactivity across separate measures of restraint and disinhibition. Therefore, a simpler methodology was adopted.

Secondly, to further reduce the complexity of Fedoroff *et al.*'s (2003) study for this preliminary experiment, only one cued food was used. Thus, participants were either exposed to a pizza cue, or were exposed to the same environment in the absence of pizza. Following this, their subjective appetite (desire to eat and craving) for this food and for the non-cued foods was compared separately in the pizza-cue, relative to the no-cue, condition. It was expected that if the effects of food-cue exposure were specific to the cued food for some individuals, then only appetite for

pizza should be greater in the pizza-cue, relative to the no-cue, condition for these individuals. Appetite for the non-cued foods should not differ after cueing with pizza relative to in the absence of cue exposure. Although this methodology was desirable because it provided a relatively simple method to assess food-cue reactivity in this initial experiment, it must be noted that it did limit the extent to which true cue specificity could be demonstrated. In particular, it was impossible to determine the extent to which food-cue exposure had an exclusive effect on intake of that food for a particular group of individuals.

The final differences in the methodology used here were, firstly, that participants were tested while they were non-food deprived, i.e., immediately after consuming a fixed lunch. As suggested in Chapter 2 (Part II) the decision to test participants in this state followed Weingarten's (1985) suggestions that exposure to a food-cue can motivate eating behaviour even in the absence of nutritional need. Secondly, in response to one of the concerns associated with the methodology used by Fedoroff *et al.* (2003), in Experiment 1 the non-cued foods comprised one sweet (cookies), and one savoury (chips), food. In Fedoroff *et al.*'s (2003) study, only one non-cued food was used and this comprised very different sensory characteristics to the cued food (pizza and cookies). One possibility, therefore, is that the cue-specific effects observed in restrained eaters in their experiment were exaggerated by the fact that the non-cued food would not normally be consumed together with the cued food within the same course of a meal. Therefore, in this experiment the non-cued foods comprised one food (chips) which is more likely to be served within the same course of a meal as the cued food (pizza), and one food (cookies) which is less likely to be served in the same course of a meal as this food.

3.3 Method

3.3.1 Overview

Experiment 1 used a typical cue reactivity paradigm. Initially, participants were asked to consume a sandwich lunch to ensure they were non-food deprived. Participants were then exposed to the sight, and smell, of pizza (pizza-cue condition), or to the same environment in the absence of pizza (no-cue condition). Both before and after this exposure phase, participants rated their appetite for the cued food (pizza) and the two non-cued foods (chips and cookies), and rated their hunger and fullness. After cue exposure they were also offered *ad-lib* access to pizza. Following Fedoroff *et al* (2003), this phase was disguised as a taste test, and participants were asked to taste and rate the pizza presented in the exposure phase. They were invited to eat as much of the pizza as they liked in order to complete these ratings, and were told to eat as much of the pizza as they liked after the ratings were complete.

3.3.2 Design

A between-subjects design was applied. Participants were randomly assigned to either a pizza cue, or a no-cue, condition. Measures of cue reactivity (appetite ratings and *ad-lib* intake) were compared between the two conditions and across DEBQ-restraint scores and TFEQ-disinhibition scores.

3.3.3 Participants

Participants were recruited from the population of female undergraduate students at Loughborough University and were aged between 18 and 30 (UK). Twenty-eight participants were recruited into the no-cue condition, and 27 were recruited into the

pizza-cue condition. All participants were recruited via email and were financially reimbursed (5 sterling pounds) BMI was not measured

3.3.4 Measures

1 Cue reactivity

Cue reactivity was assessed using ratings of subjective appetite and a measure of *ad-lib* intake. Appetite ratings included measures of general appetite (hunger and fullness) and craving for, and desire-to-eat, the cued (pizza), and non-cued, foods (chips and cookies) (see Appendix A for examples of these). These were measured using 100-mm visual analogue rating scales. These were headed with “How hungry/full are you right now”, “How strong is your desire-to-eat pizza/chips/cookies right now?”, and “How much do you crave pizza/chips/cookies right now?” Respectively, these were anchored with the phrases “not at all hungry/full” and “very hungry/full”, “not at all” and “extremely strong” and “not at all” and “very much.”

The *ad-lib* intake measure was obtained via a disguised taste test. Participants were all presented with a plate of pizza and were asked to rate the pleasantness of its taste and smell, their desire-to-eat pizza, and also how salty and spicy they regarded the food to be. Participants were told that they had 10 minutes to complete these ratings and that they could eat as much of the pizza as they wished in order to do this. They were also told that if they completed the ratings before the allocated time, then they could help themselves to more pizza as there was plenty more in the laboratory. The pizza was presented in eight equal-sized slices (36.25 kcal per slice) heaped on a plate. Intake was assessed by recording the weight of the pizza before and after consumption.

2 Dietary restraint and disinhibited eating

Dietary restraint and disinhibition were assessed using the restraint section of the Dutch Eating Behaviour Questionnaire (DEBQ, van Strien *et al.*, 1986) (see Appendix B for this questionnaire) and the disinhibition section of the Three Factor Eating Questionnaire (TFEQ, Stunkard & Messick, 1985) (see Appendix C for this

questionnaire). The DEBQ-restraint scale was chosen because this scale has been found to measure intention to restrict, and actual restriction of food intake (Lasselle, *et al* , 1989). Furthermore, this scale has been shown to have good internal consistency and factorial validity (van Strien *et al* , 1986; Wardle, 1987). The scale contains 10 items (see Appendix B). Each item has five possible options, 'never,' 'seldom,' 'sometimes,' 'often,' and 'very often.' These responses obtain scores ranging from 1 to 5. Some items also have a 'not relevant option,' which is not scored and therefore receives zero. The total score for the scale is calculated by summing the responses and dividing by the number of items that received a score of one or above. A high score on this scale indicates a high level of dietary restraint.

The TFEQ-disinhibition scale was used as a separate measure of dietary disinhibition. This scale has been shown to have good reliability and has been validated against measures of binge eating (see Stunkard & Messick, 1985). The scale contains 16 items (See Appendix C). Items 1-13 require a true/false response. True responses receive a score of one and false items score zero apart from items 8, 10, and 12. These items score zero for true, and one for false. The remaining three items on the questionnaire (14-16) each have four possible options; 'never,' 'rarely,' 'often,' and 'always.' The first two of these receive a score of zero and the remaining two receive scores of one. The scores are then summed across the 16 items. A higher score reflects a higher level of disinhibition and a lower score reflects a lower level of disinhibition.

3.3.5 Procedure

Participants were tested between 11am and 3pm. All were instructed to refrain from eating for at least 3 hours prior to the onset of the experiment. Before arriving at the laboratory, the experiment was described as a 'taste perception study.' The participants were told that they would be asked to offer an opinion on different foods and that they would be required to consume some food. The identity of this food was not revealed.

Upon arrival, participants were asked to sign a consent form and to rate their 'hunger,' and 'fullness.' Following this, they were instructed to consume a sandwich lunch, which was prepared using 2 slices of medium cut white bread and 37.5g of mild cheddar cheese (433.88 kcal). The lunch was fixed to ensure that all individuals consumed the same amount. However, using this approach, it was important to ensure that the fixed lunch did not exceed the amount individuals would be prepared to consume. For this reason, it was set at two slices of bread.

After lunch, a set of pre-exposure appetite ratings were taken (see Section 3.3.4 for details of these measures). Following this, the participants entered a three-minute exposure period. Those in the pizza-cue condition were exposed to the sight and smell of cooked pizza (supplied by Farmfoods Freezer Centres, Blairlinn, Cumbernauld, 290kcal/100g). The pizza was placed directly in front of the participants on the table, and the participants were instructed to sit and wait until the experimenter returned. Participants in the no-cue condition were left in the same environment with no pizza present, and were also told to sit and wait until the experimenter returned. Following this exposure phase (no-cue/pizza-cue), the participants provided a second set of appetite ratings, and entered the *ad-lib* intake phase.

In the final stage of the experiment, the participants completed the disinhibition scale of the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985) and the restraint scale of the Dutch eating Behaviour Questionnaire (DEBQ-R; van Strien *et al.*, 1986).

3.3.6 Data analysis

Measures of food-cue reactivity obtained in this experiment included eight measures of subjective appetite and a measure of *ad-lib.* pizza intake. The measures of subjective appetite included ratings of, general appetite (hunger and fullness), appetite (desire to eat and craving) for the cued food (pizza), and appetite (desire to eat and craving) for two non-cued foods (chips and cookies). These ratings were taken both before and after the exposure phase. For this reason, change scores were derived from the difference between the measure of appetite taken before and after

this phase Initially in the analysis, the descriptive statistics (means and SD's) were produced for all measures of cue reactivity (change in subjective appetite and *ad-lib* intake) in both the pizza-cue, and the no-cue, condition To compare the outcome measures (*ad-lib* pizza intake, change in hunger, change in fullness, change in desire-to-eat pizza, chips, and cookies, and change in craving for these three foods) in both these conditions between-subject t-tests were used.

This experiment hypothesised that food-cue reactivity might be more closely associated with dietary disinhibition rather than restraint status. To address this hypothesis, the analysis sought to determine the extent to which the outcome measures (pizza intake and changes in appetite ratings) were modulated by restraint, or disinhibition, scores To do this, interactions between condition (no cue/pizza cue) and these dietary variables were explored for each of the outcome measures. Typically, when exploring such interactions, researchers split scores on the restraint and disinhibition scales at their median value in the sample and consequently create categorical variables which can subsequently be analysed using Analysis of Variance (ANOVA). In Experiment 1 (as in the following experiments), this approach was avoided for several reasons. Firstly, it reduces power and may produce spurious effects (see MacCallum, Zhang, Preacher, & Rucker, 2002). Secondly, for scales such as the DEBQ-restraint scale and TFEQ-disinhibition scale, it is unclear why some individuals who only have marginally different scores should be allocated to opposite groups on the basis that their scores happen to be modestly higher or lower than the median value in the sample. For these reasons, in the analyses conducted for the experiments presented in this thesis, regression analyses were used because, unlike ANOVA, this form of analysis allows associations between continuous variables to be assessed. Thus, disinhibition and restraint scores were incorporated into the analysis as continuous predictors. Since condition was a categorical variable, a dummy variable was created for this category This dummy variable distinguished between the no-cue and pizza-cue condition. Separate analyses were initially conducted to explore 1) the interactions between condition and dietary restraint, and 11) the interactions between condition and dietary disinhibition. However, since it was desirable to determine the extent to which any interactions between disinhibition scores and condition occurred irrespective of

dietary restraint, in a further analysis, dietary restraint scores were entered as a covariate to allow this variable to be controlled for statistically

In all the regression analyses pre-exposure appetite ratings were controlled for statistically. This was because, the point at which an individual starts on a scale will ultimately affect the change in this measure that these individuals can report. All analyses for the experiments presented in this thesis were conducted using SPSS Version 11 and the significance level tested was set at $p < 0.05$. The data was assessed usually parametric analyses because it was continuous data, approximated to a normal distribution, and the variance within the data was homogeneous. Two-tailed tests were used for the analyses for each experiment. This was to ensure that each analysis was powered to detect an effect in either direction (i.e., a positive and negative effect). Thus, even tests of directional hypotheses were powered to detect an association even if the hypothesis was incorrect and the association was in the opposite direction to that predicted.

3.4 Results

3.4.1 Outliers

For two participants their recorded change in desire-to-eat pizza (75mm and 78mm) was more than three standard deviations away from the mean desire-to-eat pizza, and almost doubled the next lowest value. These data points were also more than three standard deviations from the predicted value in the regression model for change in desire-to eat pizza and thereby violated one of the assumptions of regression analysis. These individuals also ate less than average amounts of pizza in the *ad-lib* intake phase suggesting that it is unlikely that they experienced such great changes in desire-to eat after cue exposure. For these reasons, they were

removed from the data set⁴. The final sample comprised 53 participants; 28 in the no-cue condition, and 25 in the pizza-cue condition.

3.4.2 Participant characteristics and baseline measures

Initially, it was desirable to ensure that participants did not differ in their subjective appetite in the two conditions prior to cue exposure, and that measures of dietary behaviour were similar in both conditions. For this reason, a series of between-subject t-tests were used to compare levels of subjective appetite (hunger, fullness, desire-to eat, and craving) before cue exposure across the two conditions, and to compare participants' scores on the dietary measures. These analyses suggested that the two groups did not differ significantly in either their DEBQ-restraint scores or their TFEQ-disinhibition scores (Table 3.1). Likewise, they revealed no significant differences in hunger, or fullness, or in subjective appetite for pizza, or the non-cued foods (Table 3.1).

⁴ Analysing the data with these outliers included did not change the extent to which specific results were statistically significant.

Table 3.1 Between-subjective t-tests, means, and standard deviations, for participant characteristics (DEBQ-restraint scores TFEQ-disinhibition scores) and baseline pre-exposure ratings in both conditions

	No-cue (n = 27)		Pizza-cue (n = 25)		T-test significance	
	Mean	SD	Mean	SD	<i>t</i>	<i>p value</i>
<i>Pre-exposure ratings</i>						
Hunger	38.79	23.30	37.78	23.94	0.12	0.904
Fullness	46.61	24.01	45.12	20.06	0.243	0.809
Desire-to-eat pizza	38.75	30.75	43.52	30.50	-0.57	0.574
Desire-to-eat chips	31.93	27.28	37.20	27.99	-0.70	0.491
Desire-to-eat cookies	42.11	27.45	45.88	29.92	-0.50	0.634
Craving for pizza	27.29	30.61	36.64	31.58	-1.09	0.279
Craving for chips	24.54	25.86	28.60	27.73	-0.55	0.583
Craving for cookies	33.43	30.63	34.48	30.71	-0.13	0.901
<i>Measures of dietary behaviour</i>						
DBEQ-restraint	2.82	0.93	2.64	1.02	1.03	0.308
TFEQ-disinhibition	7.54	3.81	6.41	3.08	0.68	0.497

3.4.3 Descriptive statistics for measures of cue reactivity

As suggested here it was initially desirable to explore the descriptive statistics for the measures of cue reactivity in the two conditions. Therefore, the means and standard deviations for changes in subjective appetite and for *ad-lib* pizza intake are summarised in Table 3.2. The results of between-subject t-tests used to compare these measures in the two conditions are also presented alongside these descriptive statistics.

It is evident that changes in desire-to-eat pizza and changes in craving for this food were significantly greater in the pizza-cue, relative to the no-cue, condition (Table 3.2). This suggests that exposure to the pizza cue had a significantly greater effect on subjective appetite for this food (Table 3.2). By contrast, there was little evidence to indicate that change in subjective appetite (desire to eat and craving) for chips, or for cookies, was greater after cueing with pizza, relative to in absence of cue exposure (Table 3.2). Somewhat surprisingly, there was also little evidence to suggest that pizza-cue exposure stimulated greater intake of this food (Table 3.2).

Table 3.2 Between-subject t-tests, means, and standard deviations, for changes in subjective appetite and for pizza intake in the no-cue, and pizza-cue, condition after cue exposure

	No-cue (n = 27)		Pizza-cue (n = 25)		T-test significance	
	Mean	SD	Mean	SD	<i>t</i>	<i>p value</i>
<i>Changes</i>						
Hunger	6.96	16.306	11.72	13.81	1.14	0.260
Fullness	-6.21	16.81	-7.68	17.49	-0.31	0.757
Desire-to-eat pizza	5.00	13.28	13.52	15.25	2.18	0.034*
Desire-to-eat chips	3.93	13.49	-0.68	12.32	-1.29	0.202
Desire-to-eat cookies	-1.18	12.32	-2.00	17.71	-0.20	0.844
Craving for pizza	-11.17	15.98	8.09	21.60	3.71	0.001*
Craving for chips	7.21	15.81	5.56	13.78	-0.404	0.688
Craving for cookies	5.86	17.13	0.36	12.59	-1.32	0.193
Pizza intake	170.35	80.48	146.03	75.06	-1.133	0.262

* denotes $p < 0.05$

3.4.4 Dietary restraint, disinhibition, and subjective appetite

To test the hypothesis of this experiment, the extent to which changes in appetite ratings after exposure to the pizza were modulated by TFEQ-disinhibition scores rather than successful dietary restraint, interactions between condition (pizza cue/no cue) and dietary behaviour (disinhibition or restraint scores) were explored using linear regression models. For change in hunger, change in fullness, and for change in subjective appetite (desire-to-eat and craving) for the test foods (pizza, chips, or cookies), the interactions between dietary-restraint scores and condition were not statistically significant (Table 3.3.) This suggests that restrained eaters did not experience significantly greater changes in subjective appetite after cue exposure than unrestrained eaters. By contrast, disinhibition scores interacted significantly with condition for change in craving for pizza (Table 3.3). As Panel A in Figure 3.1 suggests, individuals with higher disinhibition scores, compared to those with lower scores, experienced a greater change in craving for pizza in the pizza-cue, relative to the no-cue, condition. After controlling statistically for restraint status, this

interaction remained statistically significant ($B = 4.52$, $SE = 1.48$, $p = 0.004$). This suggests that irrespective of restraint scores, individuals with high disinhibition scores experienced a greater change in craving for pizza in the cued, relative to the non-cued, condition. Despite the fact that Figure 3.2 Panel A provides some evidence to suggest that individuals with higher disinhibition scores also experienced a greater change in desire-to-eat pizza than individuals with lower disinhibition scores after pizza-cue exposure, this interaction effect was not statistically significant (Table 3.3).

With respect to changes in subjective appetite (desire to eat and craving) for the non-cued foods (chips and cookies), interactions between disinhibition scores and condition failed to reach statistical significance (Table 3.3). This suggests that individuals with high disinhibition scores did not experience any greater change in subjective appetite for these foods than individuals with lower disinhibition scores after pizza-cue exposure (see Figure 3.1 and 3.2 Panels, B and C). All other interactions between disinhibition scores and condition failed to reach statistical significance (Table 3.3).

Table 3.3 Adjusted¹ parameter estimates from linear regression models for interactions between condition (no cue/pizza cue) and dietary behaviour (dietary restraint and disinhibition) for changes in subjective appetite, and for pizza intake

		<i>Disinhibition * Condition</i>			<i>Restraint * Condition</i>		
		<i>(no-cue and pizza-cue)</i>			<i>(no-cue and pizza-cue)</i>		
	<i>n</i>	<i>B</i>	<i>SE</i>	<i>p value</i>	<i>B</i>	<i>SE</i>	<i>p value</i>
<i>Changes in subjective appetite</i>							
Hunger	52	2.65	1.32	0.050	-0.96	4.47	0.830
Fullness	52	0.79	1.56	0.616	5.81	4.99	0.251
Desire-to-eat pizza	52	1.87	1.12	0.100	0.82	3.93	0.836
Desire-to-eat chips	52	-1.17	1.10	0.294	-4.80	3.53	0.180
Desire-to-eat cookies	52	1.46	1.26	0.254	0.38	4.33	0.931
Craving for pizza	52	4.35	1.50	0.006*	1.63	5.41	0.765
Craving for chips	52	0.68	1.30	0.603	0.28	4.35	0.949
Craving for cookies	52	0.38	1.32	0.776	5.69	4.33	0.195
Pizza Intake	52	-5.75	6.18	0.357	-46.73	21.02	0.031*

* denotes $p < 0.05$

¹ Adjusted for the relevant pre-exposure rating

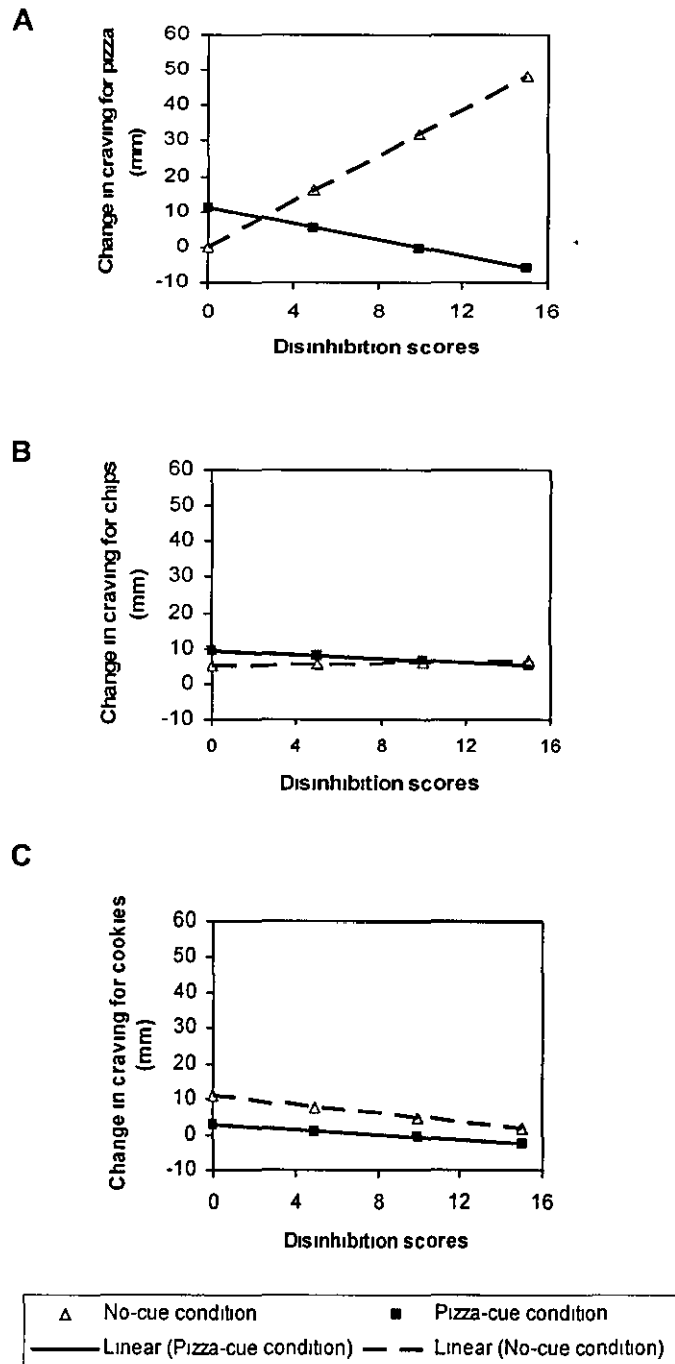


Figure 3.1 Predicted change in craving for pizza (A), chips (B), and cookies (C), (mm) for the no-cue (continuous lines), and pizza-cue conditions (dashed lines) separately, across disinhibition scores estimated using the parameter estimates from linear regression models⁵ for change in craving for chips, pizza, and cookies in the two conditions (no cue and pizza cue)⁶

⁵ These were calculated using the following formula, $y = bx + bz + c$, where b = the relevant parameter estimate from the regression model, x = disinhibition score, z = mean pre-exposure score, and c = constant coefficient from the regression model

⁶ In all models pre-exposure ratings are held at their mean value in the sample (see Table 3 1 for these values) and their parameter estimates are entered into the regression model

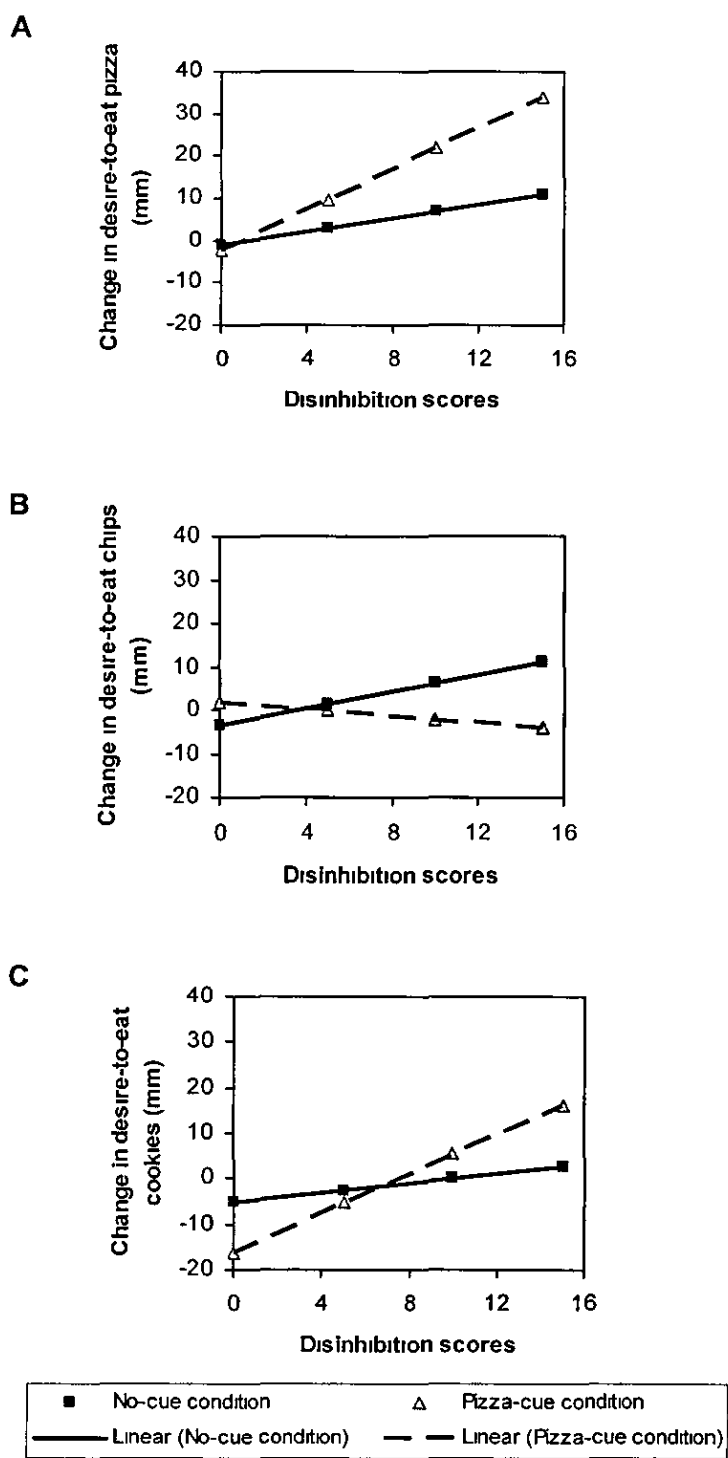


Figure 3.2 Predicted change in desire-to-eat pizza (A), chips (B), and cookies (C), (mm) for the no-cue (continuous lines) and pizza-cue conditions (dashed lines) separately, across disinhibition scores estimated using the parameter estimates from linear regression models for change desire-to-eat chips, pizza, and cookies, in the two conditions (no cue and pizza cue)⁷

⁷ In all models pre-exposure ratings are held at their mean value in the sample (see Table 3.1 for these values)

3.4.5 Dietary restraint, disinhibition, and pizza intake

There was little evidence to suggest condition interacted with disinhibition scores to predict pizza intake (Table 3.3). Rather, differences in intake were predicted by a significant interaction between DEBQ-restraint scores and condition (Table 3.3). As shown in Figure 3.3, highly restrained eaters consumed less in the pizza-cue condition than in the no-cue condition. In contrast, unrestrained eaters consumed slightly more after exposure to the pizza-cue. Even, after controlling for this association between restraint status and pizza intake, the interaction between disinhibition and condition was not statistically significant ($B = -5.32$, $SE = 6.17$, $p = 0.393$).

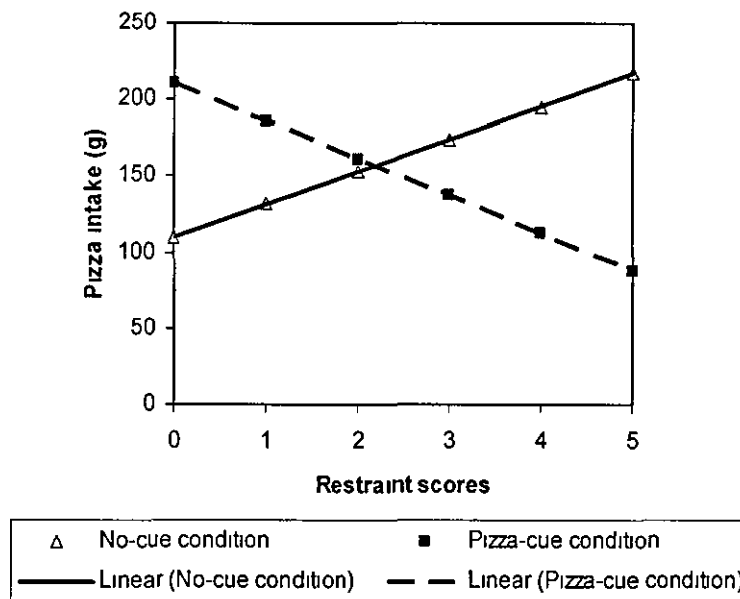


Figure 3.3 Predicted pizza intake in the no-cue (continuous lines) and pizza-cue conditions (dashed lines) separately, across restraint scores estimated using the parameter estimates from linear regression models for pizza intake in the two conditions (no cue and pizza cue)

3.4.6 Summary table of results

To reduce the complexity of the results described here, a summary table of the observed interaction effects between dietary behaviour (dietary restraint and disinhibition) and condition (no cue and pizza cue) for each of the outcome measures is provided below. This suggests that restrained eaters did not experience any greater subjective appetite after cue exposure, than unrestrained eaters. However, it does suggest that an interaction effect was observed between dietary restraint scores and pizza intake, indicating that restrained eaters consumed smaller amounts of pizza after exposure to this food. It also suggests that an interaction effect was observed between dietary disinhibition and condition for change in craving for pizza. This suggests that individuals with higher disinhibition scores experienced a greater change in craving for the cued food. All other interactions between dietary disinhibition and condition failed to reach statistical significance.

Table 3.4 Summary table of the observed interactions between dietary behaviour (dietary restraint and disinhibition) and condition (no-cue and pizza-cue) for each of the outcome measures in this experiment

	Restraint * condition (no-cue and pizza-cue)	Disinhibition* condition (no-cue and pizza-cue)
<i>Outcome measure</i>		
Change in hunger		
Change in fullness		
Change in desire-to-eat pizza		
Change in craving for pizza		✓
Change in desire-to-eat chips		
Change in craving for chips		
Change in desire-to-eat cookies		
Change in desire-to-eat cookies		
<i>Ad-lib pizza intake</i>	✓	

✓ Denotes where statistically significant interactions were observed

3.5 Discussion

The primary aim of this experiment was to assess associations between food-cue reactivity and separate measures of dietary restraint and disinhibition. It was expected that whilst levels of food-cue reactivity might not differ across an independent measure of dietary restraint, individuals with higher disinhibition scores might experience greater reactivity than individuals with lower disinhibition scores. With regards to first part of this hypothesis, there was little evidence to suggest that food-cue reactivity was associated with a restrained eating style. Restrained eaters did not report a greater motivation to eat than less restrained eaters after cue exposure, and in fact consumed significantly smaller amounts of the cued food. These findings are important because they contradict previous suggestions (e.g., Fedoroff *et al.* 1997, 2003) that restrained eaters are highly reactive to food cues. Notably, these findings are not the only results which contradict this notion. For example, it has been suggested that fasting in obese individuals attempting to lose weight does not increase motivation to eat (hunger) after brief exposure to slides depicting food items (Lappalainen, Sjoden, Hursti & Vesa, 1990). Furthermore, it has also been suggested that pure dietary restraint (which does not conflate restraint with a tendency to disinhibit) is not associated with chocolate consumption after prolonged exposure to this food (e.g., participants keeping a bag of chocolate with them for 24 hours) (Stirling & Yeomans, 2004).

The most interesting finding from this experiment relating to dietary restraint which requires further consideration was restrained eaters tendency to consume smaller amounts of food after pizza-cue exposure. As suggested above, restrained eaters were found to consume less than unrestrained eaters after pizza-cue exposure, and less than similarly restrained eaters consumed in the absence of cue exposure. The reason for this is unclear. However, one possibility is that in the presence of a food cue restrained eaters were explicitly forced to inhibit the desire to eat generated by this cue, and this caused them to consume smaller amounts of this food in the subsequent *ad-lib* taste test. This explanation is adapted from Tiffany's (1990) model of drug-cue reactivity. Tiffany's (1990) model was introduced in Chapter 2

(see section 2.6.2). This model proposes that drug cues can automatically elicit drug use. Thus, when exposed to a drug, drug users will automatically administer this drug. According to Tiffany (1990), to abstain from drug use, individuals must recruit non-automatic cognitive processes to inhibit automatic cued responses in the presence of drug cues. Thus, one possibility is that, as a consequence of actively inhibiting their food intake, restrained eaters might have reduced their food intake. However, the extent to which Tiffany's (1990) model of cue reactivity can accurately account for the behaviour of restrained eaters in this experiment is unclear. This is because, to date, this model has not been sufficiently tested. Indeed, only two studies have provided evidence to suggest that restrained eaters might recruit non-automatic cognitive processes in an attempt to combat the automatic action plans to eat in the presence of food cues. Both these studies found that restrained eaters perform poorer on a concurrent cognitive task than unrestrained eaters when cued with the thought of their favourite food, but not when cued with the thought of their favourite holiday (Brunstrom & Witcomb, 2004; Green, Rogers, & Elliman, 2000,). This was presumably because, when cued with the thought of food, these individuals were recruiting non-automatic cognitive processes to inhibit automatic action plans to eat.

Given the minimal amount of evidence in support of using Tiffany's (1990) model to describe food-cue reactivity, at present, the idea that restrained eaters recruit non-automatic processes to inhibit their food intake in the presence of food cues is purely speculative. To provide support for this speculation, future studies are required to investigate the feasibility of generalising from Tiffany's (1990) model to explain food-cue reactivity in restrained eaters. In particular, future studies are required to scrutinize exactly why restrained eaters experience interference on a cognitive task when they are cued with the thought of food as observed in the studies by Green *et al* (2000) and Brunstrom and Witcomb (2004). Although Tiffany's (1990) model would suggest that this is to inhibit automatic action plans to eat triggered by food cues, at present there is no empirical support for this. If evidence for this is generated, the next step might be to evaluate the consequences of this. Tiffany (1990) suggests that non-automatic process recruited to inhibit drug use cause urges and cravings for the cued drug. However, there is little evidence from this experiment to suggest that after cue exposure restrained eaters

experienced greater craving for, or a greater desire-to-eat, the cued food than unrestrained eaters. In addition to this, evidence should also be obtained to support the possibility suggested here, i.e., that reduced intake after cue exposure in restrained eaters might result from recruiting these non-automatic cognitive processes.

Given that there is little evidence to support the proposal that reduced intake in restrained eaters after cue exposure is a result of inhibitory cognitions, alternative explanations for this observation must be considered. One alternative explanation is that exposure to the pizza cue threatens the dietary goals of restrained eaters, and consequently forces them to inhibit their intake. Lowe and colleagues (Lowe, 1995, Lowe, Whitlow, & Bellwoar, 1991) have found that dieters dramatically reduce their intake following forced consumption of a preload. Lowe (1995) interprets these findings as suggesting that a high calorie preload provides an obvious threat to these individuals' dietary goals and subsequently forces them to limit their intake. In a similar way, exposure to a pizza cue closely after a sandwich lunch might threaten restrained eaters' dietary goals, forcing them to limit their subsequent intake. However, again, this possibility is purely speculative and requires future attention

Finding that dietary restraint was not associated with greater food-cue reactivity in this experiment was not particularly surprising. This is because it was in fact hypothesised that food-cue reactivity might be more closely associated with a measure of dietary disinhibition, rather than with a pure measure of dietary restraint. Partly consistent with this hypothesis, the results suggest that the TFEQ-disinhibition scale was associated with change in craving for pizza after brief exposure to this food, such that individuals with the highest scores on this scale experienced the greatest changes in craving. However, somewhat surprisingly, this scale was not associated with change in desire-to-eat pizza after cue exposure. Given that craving is likely to reflect an intense desire to eat (Pelchat, 2002, Weingarten & Elston, 1990;), it would be assumed that if change in craving was elevated in disinhibited eaters, change in desire-to-eat would also be greater in these individuals. One possible explanation for disinhibited eaters' tendency to report a greater change in craving, but not a greater change in desire-to-eat, might be that

craving in fact reflects something other than an intense desire to eat. For example, Rogers and Smit (2000) suggest it might represent the conflict between desire for that food because of the sensory pleasure it evokes, and attempts to resist consumption of it because of its perceived negative nutritional content (i.e., the conflict between 'naughty' but 'nice'). However, given that there was a trend for disinhibited eaters to experience a greater desire to eat after cue exposure (see Figure 3.2, Panel A), the most parsimonious explanation is perhaps that the experiment lacked power to detect a significant association between this measure of appetite and dietary disinhibition.

In this experiment, in addition to assessing changes in subjective appetite for the *cued* food across measures of disinhibition, changes in appetite for two *non-cued* foods was also assessed in an attempt to determine the specificity of any cued responses across this dietary measure. Notably, disinhibited eaters did not experience greater subjective appetite (craving and desire to eat) for either of the non-cued foods (chips and cookies). These findings are interesting because they suggest that food-cue exposure might elicit a greater subjective appetite in disinhibited eaters, but that this motivation to eat is exclusive to the food which has been cued. This is consistent with Weingarten's proposals (Weingarten, 1985) regarding conditioned meal initiation. He suggests that the effects of a food cue will be to exclusively motivate intake for the cued food.

Unfortunately, in this experiment it was impossible to determine the potential specificity of actual eating behaviour in disinhibited eaters. This was because a measure of intake was only obtained for the cued food. However, using this measure it was possible to determine the extent to which food-cue exposure stimulated greater food intake in these individuals. Given that these disinhibited eaters experienced a greater change in subjective appetite for the cued food, it might be expected that these individuals would also consume larger amounts of this food than less disinhibited eaters. However, this experiment failed to provide any evidence for this. One potential reason for this is that the measure of *ad-lib* intake used in this experiment was insensitive to the effects of cue exposure on food intake for disinhibited eaters. In this experiment, the measure of *ad-lib* intake was

obtained in a disguised taste test. Participants were instructed to taste the food and then rate its sensory characteristics. They were told that once these ratings were complete they *could* eat as much or as little of the food as they desired. However, this approach is problematic because it leads participant to believe that the aim of the phase is for them to merely taste and rate the food, rather than to eat as much as they desire. Thus, given this, it is unclear whether the taste test approach utilised in this experiment provided a valid measure of the amount individuals would *really* like to consume. This was not the only limitation associated with this measure. Another problem was that the pizza was presented in average-sized slices. Therefore, one possibility is that the participants were controlled by the portion size of the pizza slices presented. They might have felt that once intake of one pizza slice was initiated, the full slice had to be consumed. Given that these methodological issues might account for the failure to observe greater food intake in disinhibited eaters, Experiment 2 utilised a different methodological approach which addressed these limitations.

In summary, this experiment provided little evidence to suggest that food-cue reactivity is associated with dietary restraint when a measure of restraint is used which does not conflate dietary restriction with disinhibited eating. Rather, this experiment provided some evidence to suggest that food-cue reactivity might be associated with a measure of dietary disinhibition. Individuals with high disinhibition scores reported a greater change in appetite for the cued food. However, they did not consume greater amounts of this food. Given that the measure of *ad-lib* intake used in this experiment suffered several limitations, Experiment 2 aims to address these limitations.

PART II: EXPERIMENT 2

3.6 Introduction

The aim of Experiment 2 was to re-explore the hypothesis tested in Experiment 1 using an improved version of the methodology. One concern in Experiment 1 was that the measure of *ad-lib* intake did not provide an adequate measure of participants desired intake. This was because, firstly, this phase was disguised as a taste test, thus participants believed that the aim of the phase was for them to merely taste and rate the food. Secondly, presenting the pizza in pre-defined slices might have served to control the amount of food that participants ate. To address these concerns, in Experiment 2, a different approach to assess *ad-lib* intake was adopted. Rather than using a disguised taste test, in this experiment participants were merely told to eat as much or as little of the test food as they desired in the *ad-lib* intake phase. This approach was more appropriate because it signals to the participant that the aim of the phase is for them to eat as much as they like. In addition to this, foods were presented in bite-size pieces to eliminate the possibility that the portion size offered to participants controls the amount that they subsequently eat.

Potentially the greatest limitation associated with Experiment 1 was its failure to adequately assess cue specificity across measures of restraint and disinhibition. Measures of subjective appetite for the cued food and for the two non-cued foods made it possible to determine the extent to which cue exposure generated an exclusive subjective appetite for the food which had been cued. However, in the absence of a measure of intake of a non-cued food, it was impossible to determine whether food-cue exposure motivated greater intake of the cued food in these individuals but did not motivate greater intake of other non-cued foods. To address this issue, Experiment 2 assessed *ad-lib* intake of both the cued, and a non-cued, food.

As suggested previously, Fedoroff *et al*, (2003) explored the specificity of cued intake in restrained eaters defined according to Herman and Polivy's Restraint

Scale. However, as noted, one important feature of their study was that the cued and non-cued foods used were quite different (sweet and savoury). The implication of this is that these foods would not be served together within the same course of a meal. Therefore, cue-specific intake observed in this study might reflect the fact that individuals may have a tendency to select one or other of the foods almost exclusively. For example, if individuals have a desire to eat a 'sweet' food they will consume the sweet food but are unlikely to consume any of the savoury food. Thus, this design might in fact exaggerate any cue-specific effects. Experiment 2 sought to address this issue by offering participants two foods that are likely to be consumed within the same course of a meal (pizza and chips). These foods were presented simultaneously to participants to allow them to *choose* between the two foods. The foods chosen were chips and pizza. Participants were exposed to one of these foods (chip-cue or pizza-cue), or to the same environment in the absence of cue exposure (no-cue condition), and were then offered *ad-lib* access to both foods.

As in Experiment 1, a principle similar to that used by Fedoroff *et al* (2003) (see section 3.2) was employed in this experiment to assess the evidence for cue specificity across the measures of dietary restraint and disinhibition. To recap, this principle assumes that if food-cue reactivity reflects a cue-specific response then only appetite for the cued food should increase after cue exposure. Thus, intake of a particular food should be greater after cueing with that food but not after cueing with a different food. Applied to the current methodology, this would suggest that relative to intake in the absence of cue exposure (no-cue condition), intake of chips should be significantly greater after cueing with chips (chip-cue condition), but not after cueing with pizza (pizza-cue condition). In a similar way, it would suggest that relative to intake in the absence of cue exposure (no-cue condition), intake of chips should be significantly greater after cueing with chips (chip-cue condition), but not after cueing with pizza (pizza-cue condition).

In summary, this experiment sought to address the limitations associated with Experiment 1. Most importantly, it employed a methodology which allowed exploration of the effects of cue exposure on intake of not only the cued food, but also of non-cued foods. This is important because it can determine the *specificity* of cue exposure on food intake. In addition to this, this experiment was designed to

improve the measure of *ad-lib* intake. Rather than using a disguised taste test, in this experiment participants were merely told to eat as much or as little of the test food as they desired in the *ad-lib* intake phase. To avoid influencing participants' intake by providing the test food in particular portion sizes, in this experiment test foods were presented in bite-size pieces.

3.7 Method

3.7.1 Overview

Following Experiment 1, cue reactivity was assessed in non-food deprived participants. Thus, to ensure that participants were replete prior to cue exposure, they were offered a buffet-style lunch at the outset. This allowed participants the freedom to consume as much food as they required to reach satiety. The decision to offer participants a buffet-style lunch in this experiment rather than a fixed lunch was motivated by the fact that in Experiment 1 the fixed lunch was not sufficient to bring about satiety in some individuals.

In the exposure phase of this experiment, participants were exposed to, the sight and smell of pizza (pizza-cue condition), the sight and smell of chips (chip-cue condition) or the same environment in the absence of pizza or chips (no-cue condition). Both before and after this, participants rated their appetite for the food which had been cued (cued food) and the food which had not been cued (non-cued food), and rated their hunger and fullness. After cue exposure all participants were offered *ad-lib* access to the two foods (pizza and chips). The final phase involved completing the various questionnaires. In addition to completing the DEBQ-restraint scale and the TFEQ-disinhibition scale, this phase also involved completing an awareness questionnaire. This measure was introduced in this experiment because it became apparent that it is important to ensure that any reactions to the food cues observed do not merely result from participants behaving in a way in which they feel they are expected to behave by the researcher.

3.7.2 Participants

One hundred and twenty participants were recruited from the population of female undergraduate students at Loughborough University (UK) (mean BMI = 23.51, SD = 3.70). Thirty were recruited into the no-cue condition, 30 into the pizza-cue condition, and 30 into the chip-cue condition. All participants were aged between 18 and 30, and were recruited via email. They received financial reimbursement for their participation (5 sterling pounds).

3.7.3 Design

Again, a between-subjects design was applied. Participants were randomly assigned to one of three conditions, a pizza cue condition, a chip-cue condition, or a no-cue condition.

3.7.4 Measures

1. Cue reactivity

Appetite ratings used in this experiment were almost identical to those used in Experiment 1. Appetite ratings included measures of general appetite (hunger and fullness) and craving for, and desire-to-eat, pizza and chips (see Appendix A for examples of these).

Ad-lib intake was assessed in this experiment by presenting participants with chips and pizza simultaneously and asking them to eat as much or as little of the food as they desired. Pizza was presented in bite-size pieces heaped on a plate. Chips were presented as manufactured on a separate plate. Participants were told they had as much time as they liked to consume the foods. Before and after consumption, the weight of the two foods was recorded and used to obtain a measure of intake of pizza and chips for each participant.

2 Dietary restraint and disinhibited eating

Dietary restraint and disinhibition were assessed as in Experiment 1.

3 Awareness questionnaire

An awareness questionnaire was issued at the end of the experiment to ensure that participants were not aware of the aims of this experiment. This questionnaire asked i) "What do you think was the purpose of this experiment?", ii) "In this experiment I measured your consumption of pizza and chips. Do you know why?" iii) "Did you feel you were expected to eat certain amounts of these foods?", iv) "I did expect you to eat more food than you might usually do. Which food? pizza, chips, pizza and chips (please circle)," and v) "You were asked to rate your cravings for food at several points throughout the experiment. Do you know why so many ratings were taken?". These questions were displayed on separate sheets of paper and participants were instructed to turn to the next page only when their answer to the previous question was complete.

3.7.5 Procedure

The procedure used in this experiment was different to that used in Experiment 1 in several ways. Firstly, the sandwich-lunch stage was replaced by a buffet-style lunch. This buffet consisted of three sandwiches (ham, cheese, chicken), one and a half sausage rolls, six scotch eggs, three handfuls of original flavoured Pringles, two large oranges, six Jaffa cakes, and a glass of water. By asking participants to eat until they felt 'comfortably full', we ensured that participants were non-food deprived prior to the cue/no-cue exposure.

Secondly, this experiment was not described as a taste perception study. This is because the *ad-lib* intake phase was no longer disguised as a taste test. Rather, this experiment was described as an investigation exploring the effect of appetite and eating on mood. The participants were told that they would be asked to rate their appetite and mood, and that they would be required to consume some food.

Consistent with the cover story, the pre- and post-exposure rating included a set of mood ratings. Participants were asked how depressed (“How depressed (sad) do you feel right now?”), irritable (“How irritable do you feel right now?”), frustrated (“How frustrated do you feel right now?”), angry (“How angry do you feel right now?”) and anxious (“How anxious (nervous) do you feel right now?”) they felt at that moment in time

Thirdly, in the exposure stage in this experiment, participants were exposed to the sight or smell of either cooked pizza (pizza-cue condition), or cooked chips (chip-cue condition), or the same environment in the absence of food (no-cue condition), for three minutes. Again, in the food-exposure conditions, the food was placed directly in front the participant on the table at which they were sat. During this exposure phase, participants were instructed to sit and wait until the experimenter returned. After completing post-exposure ratings, participants were presented with both pizza and chips, simultaneously, during the *ad-lib* intake phase and asked to consume as much of these foods as they desired.

3.7.6 Data analysis

In this experiment the effect of cue exposure (no cue, pizza cue, or chip cue) on general subjective appetite (hunger and fullness), subjective appetite (desire to eat and craving) for chips and pizza, and *ad-lib* intake of these foods was assessed. Since subjective appetite was assessed before and after cue/no cue exposure, change scores were derived from the measure of appetite taken before and after this exposure phase. As in Experiment 1, initially it was desirable to assess the descriptive statistics (means and SD's) for the *ad-lib* intake and change in subjective appetite across the three conditions. Each outcome measure was compared across the conditions using a series of one-way ANOVA's. Where significant differences were observed, Bonferroni post-hoc tests were used to assess the differences between the three conditions

To determine the extent to which food-cue reactivity was associated with dietary restraint and dietary disinhibition, and the extent to which this was specific to the

cued food, interactions were explored between condition (no cue, pizza cue, chip cue) and the dietary measures (dietary restraint and disinhibition) for each of the outcome measures. As in Experiment 1, regression analysis was used for this as it allows the dietary measures to be entered as continuous variables. To compare the three experimental conditions (no-cue, pizza-cue, chip-cue) in this analysis the categories were converted into *two* dummy variables as described by Aiken and West (1991). In dummy coding for three categories, one category is coded as a reference and the two other categories are compared with this reference category. This creates two dummy variables. The reference category is assigned a value of '0' in both dummy variables, and the comparison group for each dummy variable is assigned a value '1' for that variable only (Aiken & West, 1991). Given that it was important to compare the no-cue condition with both cued conditions (no-cue and pizza-cue) in this experiment, the no-cue condition was coded as the reference variable, and the two other conditions were coded as the comparison groups. This coding system is shown in Table 3.5. The first dummy variable compared the no-cue condition with the pizza-cue condition. The second dummy variable compared the no-cue condition with the chip-cue condition. Notably, both dummy variables and their interaction effects (dummy variable * everyday dietary behaviour [dietary restraint and disinhibition]) are entered into the regression model simultaneously.

Using the analysis described above, interactions between each of the dummy variables and each of the measures of everyday dietary behaviour were observed for every outcome measure (change in hunger, change in fullness, change in desire-to-eat pizza, change in desire-to-eat chips, change in craving for pizza, change in craving for chips, pizza intake and intake of chips). These interactions are described in the following section as the interaction between the comparison variable (pizza-cue, or chip-cue, condition) and the measure of everyday dietary behaviour, when the reference is the no-cue condition.

As in Experiment 1, in the regression analyses used here, pre-exposure ratings for the measures of subjective appetite were controlled by entering the relevant pre-exposure variable as a covariate into the regression model. Also, separate analyses were initially conducted to explore 1) the interactions with dietary restraint, and 2) the interactions with disinhibition. However, since it was desirable to determine the

extent to which any interactions between disinhibition scores and condition occurred irrespective of dietary restraint, the disinhibition model was repeated with dietary restraint scores entered as a covariate.

Table 3.5 Dummy variable coding

No-cue condition = Reference group		
	Dummy variable 1	Dummy variable 2
No-cue condition	0	0
Pizza-cue condition	1	0
Chip-cue condition	0	1

3.8 Results

3.8.1 Participant characteristics and baseline measures

To test that the three experimental groups did not differ in their appetite ratings prior to cue exposure (i.e., after the buffet-lunch), and to ensure that there were no differences in restraint and disinhibition scores across the three experimental groups, a series of one-way between-subject ANOVA's were used. The groups did not differ significantly in their DEBQ-restraint scores (Table 3.6). However, there was a significant difference between their TFEQ-disinhibition scores (Table 3.6). Post-hoc tests (Bonferroni) suggested that these scores were significantly higher in the pizza-cue condition relative to both the no-cue condition ($p = 0.009$) and the chip-cue condition ($p = 0.001$). The implication of this difference is discussed later.

Across conditions, reported levels of fullness, and specific appetite (desire to eat and craving) for the two test foods (pizza, and chips), were not significantly different prior to cue exposure (all $p > 0.05$). However, hunger levels did differ significantly across conditions (Table 3.6). Post-hoc tests did not highlight statistically significant differences between any of the three conditions (all comparisons $p > 0.05$). However, visual inspection of the means suggests that hunger was greater in the no-cue condition relative to both the cued conditions. For this reason, in the subsequent regression analysis, pre-exposure hunger ratings were

also controlled for statistically by entering them as a covariate into the regression models for each of the independent variables

Table 3 6 One-way between-subject ANOVAs, means, and standard deviations, for baseline ratings (hunger, desire-to-eat pizza, desire-to-eat chips, craving for pizza, and craving for chips), and for participant characteristics (DEBQ-restraint scores TFEQ-disinhibition scores)

	No-cue (n = 40)		Pizza-cue (n=40)		Chip-cue (n=40)		ANOVA significance	
	Mean	SD	Mean	SD	Mean	SD	F	p
							(2 117)	
<i>Baseline ratings</i>								
Hunger	15 83	18 31	9 10	10 06	9 05	8 70	3 56	0 032*
Fullness	72 73	16 24	69 88	17 54	76 73	10 97	2 05	0 133
Desire-to-eat pizza	45 55	27 63	35 78	26 92	51 50	26 92	0 43	0 649
Desire-to-eat chips	33 55	28 17	25 00	23 92	30 88	40 99	1 37	0 259
Craving for pizza	25 23	25 11	17 51	21 85	18 03	22 73	0 37	0 692
Craving for chips	17 08	20 08	13 55	19 67	14 15	19 07	0 66	0 518
<i>Participant characteristic</i>								
DEBQ-restraint scores	2 71	0 78	2 82	0 86	2 60	0 78	0 76	0 471
TFEQ-disinhibition scores	7 10	2 84	9 05	3 24	6 30	3 17	8 30	<0 001*

* denotes $p < 0.05$

3.8.2 Descriptive statistics for measures of cue reactivity

As suggested above, it was initially desirable to explore the descriptive statistics for the measures of cue reactivity across the three conditions. Therefore, the means and standard deviations, for changes in subjective appetite and for *ad-lib* intake are summarised in Table 3.7. The results of one-way between-subject ANOVAs used to compare these measures across the three conditions are also presented alongside these descriptive statistics

Changes in hunger differed significantly across the three conditions (Table 3.7). Post-hoc tests (Bonferroni) suggested that change in hunger was significantly greater after exposure to the pizza cue relative to in the absence of cue exposure ($p < 0.001$). Changes in subjective appetite (desire to eat and craving) for both the test foods (chips and pizza) also differed significantly after cue exposure (Table 3.7). Post-hoc tests suggested that relative to the no-cue condition, change in desire-to-eat and craving for pizza were significantly greater after cueing with this food (both $p < 0.05$), but not after cueing with chips (both $p > 0.05$). Likewise, they suggested that changes in subjective appetite for chips were only greater after exposure to the chip cue (both $p < 0.05$). After exposure to the pizza cue, these changes did not differ to changes observed in the absence of cue exposure (no-cue condition) (both $p > 0.05$). By contrast, there was little evidence to suggest that intake of pizza or chips differed significantly across the three conditions (Table 3.7).

Table 3.7 One-way between-subject ANOVAs, means, and standard deviations, for changes in subjective appetite, and for *ad-lib* intake in the no-cue, pizza-cue, and chip-cue, condition

	No-cue (n= 40)		Pizza-cue (n=40)		Chip-cue (n=40)		ANOVA Significance	
	Mean	SD	Mean	SD	Mean	SD	$F_{(2,117)}$	p
<i>Changes</i>								
Hunger	5.23	7.47	15.38	16.57	7.38	12.83	6.84	0.002*
Fullness	-2.73	15.86	-2.65	19.85	-3.03	16.80	0.01	0.995
Desire-to-eat pizza	-0.13	19.47	26.03	29.28	11.28	19.92	13.55	<0.001*
Desire-to-eat chips	-0.63	18.32	4.75	14.32	15.65	21.05	8.39	<0.001*
Craving for pizza	7.28	21.10	23.68	28.04	8.58	14.83	6.87	0.002*
Craving for chips	3.88	12.15	6.90	12.66	15.98	23.06	5.67	0.004*
<i>Intake</i>								
Pizza	83.96	46.41	75.51	43.83	69.99	36.23	1.07	0.345
Chips	44.19	26.66	46.30	37.88	58.54	45.86	1.65	0.196

* denotes $p < 0.05$

3.8.3 Food-cue reactivity and dietary behaviour

There was little evidence of significant interactions between either of the dietary measures and the pizza-cue condition (reference = no-cue condition) for any of the changes in subjective appetite, or for *ad-lib* intake of either of the test foods (Table 3.8). Likewise, interactions between the dietary measures and the chip-cue condition (reference = no-cue condition) were not statistically significant for changes in hunger, fullness, subjective appetite for pizza, or chips, or for *ad-lib* pizza and chip intake (Table 3.8).

Table 3.8 Adjusted¹ parameter estimates from linear regression models for interactions between the pizza-cue, or chip-cue, condition (Reference, no-cue condition) and dietary behaviour (dietary restraint and disinhibition) for changes in subjective appetite, and for pizza intake

			Disinhibition*condition (no-cue and pizza-cue)			Restraint*condition (no-cue and pizza-cue)		
	<i>n</i>	<i>Ref</i>	<i>B</i>	SE	<i>p</i>	<i>B</i>	SE	<i>p</i>
<i>Hunger</i>								
Pizza-cue	120	No-cue	-0.84	0.690	0.225	-2.18	2.54	0.460
Chip-cue	120	No-cue	0.03	0.697	0.957	0.81	2.65	0.761
<i>Fullness</i>								
Pizza-cue	120	No-cue	0.81	0.98	0.409	2.15	3.56	0.547
Chip-cue	120	No-cue	0.003	0.99	0.997	0.72	3.73	0.847
<i>Desire-to-eat pizza</i>								
Pizza-cue	120	No-cue	-0.05	1.48	0.097	1.17	5.41	0.829
Chip-cue	120	No-cue	-0.30	1.49	0.842	-1.91	5.65	0.735
<i>Desire-to-eat chips</i>								
Pizza-cue	120	No-cue	-1.93	1.18	0.105	3.48	4.41	0.431
Chip-cue	120	No-cue	-0.79	1.19	0.507	4.38	4.60	0.344
<i>Craving for pizza</i>								
Pizza-cue	120	No-cue	0.07	1.24	0.950	0.27	4.57	0.953
Chip-cue	120	No-cue	-0.25	1.25	0.840	-3.72	-0.07	0.437
<i>Craving for chips</i>								
Pizza-cue	120	No-cue	-1.67	0.97	0.088	2.32	3.58	0.519
Chip-cue	120	No-cue	-0.28	0.97	0.775	1.99	3.98	0.519
<i>Pizza Intake</i>								
Pizza-cue	120	No-cue	3.30	3.04	0.279	19.06	11.41	0.098
Chip-cue	120	No-cue	3.01	3.11	0.336	19.07	11.99	0.115
<i>Chips intake</i>								
Pizza-cue	120	No-cue	3.14	2.67	0.242	2.26	10.02	0.822
Chip-cue	120	No-cue	2.67	2.73	0.330	-5.56	10.53	0.598

* denotes $p < 0.05$

¹ Adjusted for pre-exposure hunger and for relevant pre-exposure rating

3.8.4 Awareness Questionnaire

To explore the extent to which the results obtained in this experiment could be attributed to participants' awareness of the aims of the experiment, an awareness questionnaire was issued in the final phase of the experiment. Responses to this questionnaire are summarised in Table 3.9. These responses suggested that the majority of participants were unaware of the overall purpose of the experiment. Participants either believed the cover story provided at the outset, or presumed the aim of the study was to explore dietary habits.

With regards to the more specific aims of the study, approximately 27% of participants suggested that they were expected to eat certain amounts of the foods presented in the *ad-lib* phase. However, only seven out of 40 participants in the chip-cue condition felt that they were expected to eat more chips. Slightly more participants (13 participants out of 40) in the pizza-cue condition suggested they were expected to consume larger amounts of pizza. By contrast, 25% of participants provided answers suggesting that they were aware of the interest in the effect of cue exposure on subjective appetite.

Table 3.9 Summary of responses to the awareness questionnaire All total are given in percentages

Question	Response (%)			
	Yes/ aware	No/ unaware	Indicated pizza in pizza-cue condition	Indicated chips in chip- cue condition
What do you think was the purpose of this experiment?	8.33	91.67	—	—
In this experiment I measured your consumption of pizza and chips. Do you know why?	0.83	99.17	—	—
Did you feel you were expected to eat certain amounts of food?	26.67	73.33	—	—
I did expect you to eat more food than you might usually do. Which food?	—	—	32.5	17.5
You were asked to rate your craving for food at several points throughout the experiment. Do you know why so many ratings were taken?	24.17	75.83	—	—

3.9 Discussion

As in Experiment 1, food-cue reactivity was found to share little relationship with dietary-restraint status in this experiment. Restrained eaters did not differ in their subjective appetite or intake after exposure to the same food as that used in Experiment 1 (pizza), or after exposure to a different food (chips). These findings are important because they provide further support to suggest that, contrary to previously published work, restrained eaters are not any more reactive to food-cues than less restrained eaters

In Experiment 1, it was suggested that restrained eaters consume smaller, not greater, amounts of food than unrestrained eaters after cue exposure. However, this finding was not replicated in the present study for either intake of pizza or chips. One possibility is that this finding was particular to the method used to assess *ad-lib* intake in Experiment 1 (i.e., the taste test methodology). However, an alternative possibility is that restrained eaters did not find it necessary to actively inhibit their pizza intake in this experiment because they were relatively more satiated after lunch than in Experiment 1⁸. Indeed, Tiffany (1990) proposes that in the absence of physiological need for a cued substance, individuals attempting to abstain from use of the substance will not automatically be motivated towards it during cue exposure, and therefore cognitive inhibition to prevent this automatic behaviour is unnecessary. Consistent with this, Brunstrom and Witcomb (2004) reported that restrained eaters do not cognitively suppress any automatic plans to eat in the presence of a cued food while satiated. These authors found that while cued with the thought of food, performance on a concurrent task was not significantly different in restrained, and unrestrained, eaters after they had recently consumed lunch. Thus, given that restrained eaters in the present study were relatively more satiated than in Experiment 1, it is possible that these individuals did not consume smaller amounts after cue exposure because food-cue exposure did not motivate this inhibited response in the absence of physiological need. However, given that this

⁸ In Experiment 2, mean fullness rating after the buffet lunch was 73.11. By contrast in Experiment 1, the mean rating after the fixed lunch was 45.87.

possibility is purely speculative, future studies should consider this possibility further.

Notably, in Experiment 1, there was some evidence to suggest that food-cue reactivity might be associated with dietary disinhibition. Indeed, individuals with high disinhibition scores were found to experience greater craving for pizza after exposure to this food, but were not found to consume greater amounts of this food. In the present study, using an improved measure of *ad-lib* intake, again individuals with high disinhibition scores did not consume greater amounts of a cued food, and in fact were not even found to experience any greater craving for this food than individuals with lower disinhibition scores. The reason disinhibited eaters did not experience greater craving for the cued food in this experiment is unclear. However, participants did report being more satiated after lunch in this experiment. Therefore, this represents one difference relative to Experiment 1 which might account for the failure to observe greater craving in these individuals. However, this represents only one possibility and without empirical evidence to support this, it remains purely speculative.

Before formulating firm conclusions regarding the associations between food-cue reactivity and the dietary behaviours, it is important to consider that there were several limitations associated with the present experiment. The first limitation relates to the measure of *ad-lib* food intake, and also applies to Experiment 1. In both experiments, it has been assumed that the measure of *ad-lib* intake obtained in the no-cue condition provides a measure of intake of the test food in the absence of prior exposure to this food, i.e., it provides a non-cued measure. However, one possibility which has not previously been considered is that intake in this condition is also cued, and therefore does not provide an adequate control measure. This cueing might occur as brief exposure to the sight and smell of a food in the *ad-lib* intake cues appetite for this food. Indeed, there is no logical reason why even this brief exposure should not cue appetite for a food. In fact, Weingarten (1985) suggested that there is no such thing as 'unsignalled meals.' This is because even the presentation of food immediately before a meal begins acts as a cue to stimulate intake. Furthermore, in addition to the sight and smell of food cueing appetite, there is also reason to suspect that the taste of the food as intake is initiated might cue

appetite. Support for this comes from evidence suggesting that palatability, or the taste of a food, can stimulate food intake (Bobroff & Kissileff, 1986; Decke, 1971; Price & Grinker, 1973; Rodin, 1975a; Yeomans, 1996; Yeomans, Gray, Mitchell, & True, 1997).

The possibility that *ad-lib* intake in a no-cue condition might also reflect a cued measure could account for the failure to provide even basic evidence to suggest that food-cue exposure generally increases intake of the cued food in Experiments 1 and 2, despite the fact that it increased subjective appetite for this food (see Sections 3.4.3 and 3.8.2). Although some previous studies (e.g., Fedoroff et al, 1997, 2003; Jansen *et al*, 1991,) have reported that *ad-lib* intake is stimulated by exposure to a food cue, they have typically used longer and more extensive exposure periods than used in Experiments 1 and 2. For example, Fedoroff *et al* (2003) exposed participants to the smell of baking pizza for ten minutes while they were simultaneously asked to think about pizza and to write these thoughts on paper. Therefore, as a result of this longer exposure period participants in the food-cue condition in these studies might be cued to an extent which cannot be achieved by brief cueing in the *ad-lib* intake phase. However, using this intensive cueing period is problematic because it limits the applicability of these findings to occasions outside the laboratory where individuals are intensively exposed to a food cue for a relatively long period of time. Yet, within everyday life, there are several occasions when participants are only briefly exposed to a food cue for a few minutes. For example, this brief exposure might occur when individuals are exposed to a poster advertising fast food. For this reason, it might be appropriate to avoid intensive cueing procedures.

Another limitation associated with Experiment 2 was that participants in the pizza-cue condition had significantly higher TFEQ-disinhibition scores than participants in the other conditions. Consequently, similar groups of individuals were not being tested across the three conditions. There are two possible explanations for these higher disinhibition scores in the pizza-cue condition. Firstly, it may have simply resulted from a random sampling error. However, an alternative possibility is that exposure to pizza inadvertently increased these individuals' disinhibition scores. While this latter possibility seems unlikely, particularly since disinhibition scores in

the pizza-cue condition in Experiment 1 were not significantly higher than those reported in the no-cue condition, it does require further attention. To explore this issue, all participants from the present study were contacted and asked to complete the disinhibition scale again. If these re-test scores were consistent with previous scores obtained during the experimental procedure, one would assume that higher scores in the pizza-cue condition were a result of a simple random sampling error. However, if these scores are significantly lower than those previously recorded, a re-analysis of the present data would be considered. This is because, this might suggest that exposure to pizza in this experiment inadvertently increased these scores. The results of this re-test are presented in the following section.

3.10 Re-test of TFEQ-disinhibition scores

Following the finding that disinhibition scores were elevated in the pizza-cue condition in Experiment 2, a decision was made to re-test participants' disinhibition scores. If these re-test scores were consistent with the scores obtained during the Experiment 2, one would assume that higher scores in the pizza-cue condition were a result of a random sampling error. However, if these scores were significantly lower than those previously recorded a re-analysis of the data from Experiment 2 would be considered. This is because, this might suggest that exposure to pizza in this experiment inadvertently increased these scores.

3.10.1 Method

3.10.1.1 Procedure

Participants were contacted via email approximately five months after they had originally participated in Experiment 2, and were asked to complete an on-line version of the TFEQ-disinhibition scale. They were not told that they had completed this questionnaire previously.

3.10.1.2 Data Analysis

Since the primary aim of this study was to determine the extent to which TFEQ-disinhibition scores reported in the on-line follow-up questionnaire differed to those obtained in Experiment 2 in the pizza-cue condition, a within-subjects t-test was used to compare these two scores. As a simple check of reliability, this test was also performed for the other two conditions (no-cue and pizza-cue condition).

3.10.2 Results

3.10.2.1 Participant characteristics

Thirty-one of the participants who had previously participated in Experiment 2 had left the university. Therefore, the questionnaire was received by 89 participants from the sample. Sixty-five of these responded; 19 in the no-cue condition, 26 in the chip-cue condition, and 20 in the pizza-cue condition. These respondents did not differ significantly from non-respondents in their TFEQ-disinhibition scores ($t = -0.370$, $df = 118$, $p = 0.718$), or in their DEBQ-restraint scores ($t = -1.61$, $df = 118$, $p = 0.110$) reported in Experiment 2, or in their BMI ($t = -1.27$, $df = 118$, $p = 0.207$) (see Table 3.10 for means).

Table 3 10 Means and standard deviations for participant characteristics (TFEQ-disinhibition scores, DBEQ-restraint scores, and BMI)

	Non-respondents (n = 24)		Respondents (n = 65)	
	Mean	SD	Mean	SD
TFEQ-disinhibition scores	7.36	3.16	7.58	3.39
DEBQ-restraint scores	2.57	0.72	2.82	0.86
BMI	22.99	3.74	23.84	3.58

3.10.2.2 TFEQ-disinhibition scores

TFEQ-disinhibition scores were not found to be significantly different at follow-up for participants who had been assigned to the pizza-cue condition in Experiment 2 ($t = 1.696$, $df = 19$, $p = 0.109$), or who had been assigned to the chip-cue ($t = 0.491$, $df = 25$, $p = 0.629$), or to the no-cue, condition ($t = 0.629$, $df = 18$, $p = 0.537$) (see Table 3 11 for means). In fact, rather than being lower, disinhibition scores in the pizza-cue condition were in fact marginally higher at follow-up, albeit this increase was not statistically significant.

Table 3 11 TFEQ-disinhibition scores obtained via email and in experiment 2, separately, for each condition (no-cue, pizza-cue, chip-cue)

	TFEQ-disinhibition score obtained at follow-up		TFEQ-disinhibition score from experiment 2	
	Mean	SD	Mean	SD
No-cue	7.74	0.78	7.42	3.06
Pizza-cue	10.00	3.67	8.90	3.64
Chip cue	6.85	3.52	6.58	3.04

3.10.3 Discussion

The present investigation re-examined the disinhibition scores of participants from Experiment 2 to determine the extent to which these scores were consistent with those reported in Experiment 2. The findings suggested that the disinhibition scores of participants assigned to the pizza-cue condition were not significantly different at follow-up, albeit the trend was for these scores to be marginally higher. On the basis of these findings, one can conclude, therefore, that the relatively high disinhibition scores reported in Experiment 2 in pizza-cue condition were a result of a random sampling error, rather than as a result of being exposed to pizza. The results of this re-test are also important because they highlight the re-test reliability of the disinhibition scores in the specific samples used for the research undertaken in this thesis.

3.11 Chapter Summary

Experiments 1 and 2 primarily sought to explore the extent to which food-cue reactivity is more closely associated with a tendency to disinhibit, rather than dietary restraint per se. In Experiment 1, using a basic cue reactivity paradigm, participants were exposed to the sight, and to the smell, of pizza for three minutes. Cue reactivity was then assessed using measures of subjective appetite and *ad-lib* intake. This experiment provided little evidence to suggest that food-cue reactivity was associated with dietary restraint. By contrast, individuals with high disinhibition scores were found to experience greater increases in craving after cue exposure than individuals with lower scores on this scale. However, these individuals were not found to consume larger amounts of this food. One possible explanation for these inconsistent findings was that the measure of *ad-lib* intake used in Experiment 1 lacked the sensitivity to detect differences in intake across disinhibition scores. For this reason, Experiment 2 utilised an improved measure of *ad-lib* intake. The experiment was no longer disguised as a taste test and pizza was presented in bite-size pieces rather than in slices. Yet, despite these changes, again

there was little evidence of elevated food intake in individuals with high disinhibition scores after cue exposure. Furthermore, in this experiment these individuals were not even found to experience greater craving for the cued foods.

CHAPTER 4

IMPLICATIONS OF FOOD-CUE REACTIVITY FOR EVERYDAY PORTION-SIZE SELECTION

4.1 Chapter overview

This chapter presents the findings from Experiment 3. The primary aim of this experiment was to consider the possibility that individuals who show elevated sensitivity to food cues in the laboratory consume larger amounts of food within their everyday lives. To explore this possibility, associations between measures of food-cue reactivity and everyday portion-size selections were assessed. A secondary issue considered in this experiment was the extent to which food-cue reactivity is associated with measures of everyday dietary behaviour (dietary restraint and disinhibition). The remainder of this chapter provides further details of the issues addressed in this experiment, the methodology applied, and the observed results.

4.2 Introduction

Experiments 1 and 2 sought to determine the extent to which individual differences in dietary restraint and disinhibition can predict food-cue reactivity. Following from these experiments, the present experiment aimed to identify another characteristic which might explain variation in this reactivity to food cues. Specifically, this experiment sought to determine the extent to which greater food-cue reactivity in the laboratory is associated with the selection of larger everyday portion sizes. Indeed, given that exposure to the sight and smell of food can increase food intake (e.g., Fedoroff *et al*, 1997; 2003), and that this effect is more pronounced in some individuals (e.g., Collins, 1978; Rogers & Hill, 1989), there is reason to suspect that

greater sensitivity to food cues might be associated with greater everyday food consumption. To assess this possibility in this experiment, subjective and behavioural markers of cue reactivity were assessed in the laboratory, and compared with a measure of everyday portion-size selection. It was hypothesised that those individuals who select larger everyday portions experience greater sensitivity to food cues (Hypothesis 1).

A secondary issue considered in this experiment was the extent to which food-cue reactivity is associated with measures of everyday dietary behaviour (dietary restraint and disinhibition). Again this was explored by comparing markers of food-cue reactivity in the laboratory with these dietary measures. As in Experiments 1 and 2, it was hypothesised that food-cue reactivity would be more closely associated with dietary disinhibition rather than restraint status (Hypothesis 2). Specifically, it was hypothesised that those individuals with high disinhibition scores would experience greater cue reactivity than those individuals with lower disinhibition scores. By contrast, it was expected that restrained eaters would not experience any greater cue reactivity than unrestrained eaters.

Food-cue reactivity was assessed in this experiment using a methodology similar to that used in Experiments 1 and 2. However, the methodology adopted here sought to address concerns that the measure of intake used in Experiments 1 and 2 might have compromised ecological validity. In Experiments 1 and 2, desired food consumption after cue exposure was assessed using a measure of *ad-lib* intake. This measure was chosen because it has previously been used to determine the effect of cue exposure on food intake (e.g., Cornell *et al.*, 1989, Fedoroff *et al.*, 1997, 2003; Rogers & Hill, 1989). However, measures used in the context of the laboratory should be able to explain behaviour outside the laboratory. Yet, outside the context of the laboratory there are very few occasions when we are offered *ad-lib* access to food and able to eat as much or as little as we like. Rather, in these circumstances it is more typical for the size of a meal to be selected before a meal commences. This is because, we tend to pre-select an amount of food before preparing the food to eat, or select a portion size for consumption within a restaurant or a fast food

establishment. These portion-size selections then dictate the amount of food that we consume (Diliberti, *et al*, 2004; Rolls *et al*, 2002; Rolls *et al* 2004;). For this reason, it might be more relevant to explore the effect of food-cue exposure on portion-size selection of a cued food. Thus, in Experiment 3, a measure of desired portion size replaced the measure of *ad-lib* food intake.

4.3 Method

4.3.1 Overview

In Experiment 3 a paradigm similar to that used in Experiments 1 and 2 was employed. Thus, at the outset participants were offered a buffet-style lunch to ensure they were non-food deprived. Following this, they entered an exposure phase where they were exposed to the sight and smell of pizza for three minutes. Both before and after this, they provided reactivity measures. In this experiment these included conventional appetite ratings used in Experiments 1 and 2, and a novel measure of portion-size selection as described in the preceding section. Following the procedure used in Experiment 2, this experiment was disguised as a study exploring the relationships between appetite and mood.

4.3.2 Design

Contrary to Experiments 1 and 2, Experiment 3 did not include a no-cue condition. This is because findings from Experiments 1 and 2 suggested that it is potentially difficult to achieve a truly non-cued condition since all participants might become primed by the sight of the food in the *ad-lib* intake phase. Although Experiment 3 did not incorporate a measure of *ad-lib* intake per se, the inclusion of a measure of portion-size selection of the cued food required participant's to view the food in order to judge the portion size they would like to eat. Thus, the mere sight of pizza in this portion-size selection phase might cue appetite for pizza even in the absence of prior cue exposure. For this reason, given that this was an initial attempt to

explore the effect of cue exposure on desired portion size of the cued food, it was decided that all participants would be assigned to a pizza-cue condition. Therefore, all participants were primed with the sight and smell of pizza. This design allowed associations between the independent variables (everyday portion-size selection, dietary restraint, and dietary disinhibition) and the measures of cue reactivity (changes in subjective appetite for pizza, and portion-size selection) to be assessed across a group of individuals who had been cued with pizza.

4.3.4 Participants

Thirty participants were recruited from the population of female undergraduate students at Loughborough University (UK) (mean age = 19.30, SD = 4.25). These participants were recruited by email and were financially reimbursed (5 sterling pounds). The decision to recruit 30 participants for this experiment was motivated by the fact that the experiment essentially involved only one condition. Following from Fedoroff *et al.*'s (1997, 2003) work, decisions regarding sample sizes in the experiments presented thus far in this thesis relied on their principle of approximately 30-40 participants per condition.

4.3.5 Measures

1. Cue reactivity

Again, hunger, and fullness, and craving for, and desire to eat, the cued food (pizza) were measured using 100-mm visual analogue rating scales (see Chapter 3 for details of these scales). Given that this was an initial attempt to explore the effect of food-cue exposure on desired portion size and its association with everyday portion-size selections, only measures of appetite (subjective, and portion size selection) for the cued food were included.

To obtain a measure of desired pizza portion size after cue exposure, participants were presented with a 420mm x 594mm sheet of card. The card had a diagonal line running from the bottom left to the top right hand corner, and participants were told that the corner of their selected portion size should intersect this line (examples of

this were provided) (see Appendix D for a picture of this card) Using the pizza presented during the exposure phase as a model, the participants were asked to select the amount of pizza that they would like to eat at that time. The area of this selected portion size was then calculated.

2 Everyday portion size

To obtain a measure of everyday portion size, participants were shown sets of eight photographs, each set depicted a commonly consumed food (Nelson, Atkinson, & Meyer, 1997). The series of pictures contained portion sizes ranging from the 5th to 95th centile on a distribution of portion sizes observed in The Dietary and Nutritional Survey of British Adults (Gregory, Foster, Tyler, & Wiseman, 1990). Participants were asked to use these photographs to indicate the amount of food that they typically consume. They were told that if the amount of a food corresponded exactly with the amount depicted in one of the pictures, then they should put a cross through the corresponding number on the scale. However, if the amount was slightly larger or smaller then they should indicate this by placing a cross to the left or right of the corresponding number. This response was recorded using a 9-point visual analogue scale anchored with the numbers 0 and 8. In total, nine foods were presented in this way (pasta, cornflakes, chocolate cake, potatoes, beans, lasagne, spaghetti bolognese, chips, and cheesecake). A measure of everyday portion size was then defined as the average portion-size selection for these foods.

3 Dietary restraint and disinhibited eating

Measures of dietary restraint and disinhibition were measured in the same way as described in Experiments 1 and 2 (see Chapter 3)

4. Awareness Questionnaire

An awareness questionnaire was issued at the end of the experiment to ensure that participants were not aware of the aims of this experiment. This questionnaire asked i) what do you think was the purpose of this experiment? ii) I asked you to rate your mood and appetite twice during the experiment. Do you know why? iii) In this experiment I asked you whether you would want to eat pizza and how much. Do you know why? These questions were displayed on separate sheets of paper and

participants were instructed to turn to the next page only when their answer to the previous question was complete.

4.3.6 Procedure

Before arriving at the laboratory the participants were told that the aim of the experiment was to explore the relationship between 'appetite and mood.' They were also told that they would have to rate their mood throughout the experiment and that they would be asked to offer an opinion on various foods. Finally, they were told that they would receive a buffet lunch.

Participants were scheduled for a 60-minute session between 11am and 3pm. All were instructed to refrain from eating for three hours prior to the onset of the experiment. On arrival, participants gave written consent for their participation. Following this, they were presented with a buffet lunch and were asked to eat until they felt 'comfortably full.' The items that comprised this buffet lunch were identical to those used in Experiment 2. After lunch, participants provided hunger and fullness ratings, and rated their appetite (desire to eat, and craving) for the pizza (pre-exposure appetite ratings). Consistent with the cover story, this initial set of measures also included a number of ratings relating to their current mood.

The participants were then exposed to the sight and smell of cooked pizza for three minutes. The pizza was presented in a rectangle slice, and weighed 300g (810 kcal). It was placed on a table directly in front of the participant. During this exposure phase, participants were instructed to sit and wait until the experimenter returned. After exposure, the participants provided a second set of appetite ratings, and provided their portion-size selection of pizza. Following this, the participants completed measures of dietary restraint and disinhibited eating, and recalled their everyday portion size of nine commonly eaten foods. Finally, participants completed an awareness questionnaire.

4.3.7 Data analysis

In Experiment 3, a measure of desired pizza size, and measures of subjective appetite (hunger, fullness, desire-to-eat pizza, and craving for pizza) were obtained. Initially it was desirable to assess the descriptive statistics (means and SD's) for these measures and to assess the general effect of cue exposure on subjective appetite by comparing pre- and post-cue exposure measures using within-subject t-tests. In addition to this, in this preliminary part of the analyses it was desirable to calculate the descriptive statistics for participant characteristics (dietary restraint, disinhibition, and everyday portion-size selection), and to calculate a series of Pearson Correlation Coefficients to assess the associations between each of these variables.

Following the preliminary analyses, for each measure of subjective appetite, a change score was derived from the difference between the measure of reactivity before and after cue exposure. To determine the extent to which these change scores were associated with dietary restraint, disinhibition, and average everyday portion size, separate regression analyses were used. In each of these regression models the corresponding pre-exposure appetite rating was controlled for statistically for each of the change scores by entering the relevant pre-exposure variable as a covariate into the model. To determine the extent to which any differences in subjective appetite across disinhibition scores were modulated by restraint status, further regression models were conducted for disinhibition scores which controlled statistically for restraint status by entering it as a covariate into the model.

To determine the association between desired portion size of pizza after cue exposure and the three measures of everyday dietary behaviour, a series of simple Pearson's correlations were calculated. Again, for disinhibition, it was desirable to explore these associations after controlling for dietary-restraint scores. Accordingly, the association between these scores and portion-size selection was assessed in a second analysis using linear regression and controlling statistically for restraint scores

4.4 Results

4.4.1 Participant characteristics

Table 4.1 Mean and standard deviations for participant characteristics

	n	Mean	SD
<i>Characteristic</i>			
BMI	30	22.72	2.49
TFEQ-disinhibition score	30	7.60	3.40
DEBQ-restraint score	30	2.81	0.86
Everyday portion size	30	5.67	0.88

Means and SD's for each of the participant characteristics are summarised in Table 4.1. It was desirable to determine the extent to which the dietary measures (dietary restraint, disinhibition, and everyday portion size) were associated with each other. Thus, a series of Pearson's correlation coefficients were calculated. This analysis suggested that average everyday portion size was significantly associated with disinhibition scores ($r = 0.464$, $p = 0.010$), suggesting that individuals with higher disinhibition scores do report consuming larger amounts of food in their everyday lives. However, in contrast to this, there was little evidence to suggest that individuals with high restraint scores select larger everyday portion sizes ($r = 0.074$, $p = 0.697$). Furthermore, higher restraint scores were not significantly associated with higher disinhibition scores ($r = 0.168$, $p = 0.376$).

4.4.2 Baseline measures

To eliminate the possibility that subjective appetite (hunger, fullness, desire-to-eat pizza, and craving for pizza) prior to cue exposure differed across the dietary measures, Pearson's correlation coefficients were calculated for each of the baseline measures of subjective appetite and each of the dietary behaviours. These analyses suggested that levels of fullness, hunger, desire-to-eat pizza, and craving for pizza

did not differ significantly across disinhibition scores, or the measure of everyday portion size (all $p > 0.05$). However, this analysis did suggest that restrained eaters had greater levels of hunger than unrestrained eaters prior to cue exposure ($r = 0.381$, $p = 0.038$). Thus, one possibility is that any greater reactivity observed in these individuals might result from this elevated hunger. For this reason, it was decided that in circumstances where associations were observed between dietary restraint and measures of food-cue reactivity, hunger would be entered as a covariate into the regression model to determine whether the *associations* remained statistically significant after controlling for these differences in baseline hunger.

4.4.3 Descriptive statistics for measures of cue reactivity

As suggested above it was initially desirable to explore the descriptive statistics for the measures of cue reactivity across the three conditions. The means and standard deviations for pizza intake after cue exposure and appetite ratings before and after cue exposure are therefore summarised in Table 4.2. The results of within-subject *t*-tests used to compare the measures of subjective appetite from before to after cue exposure are also shown. These findings suggest that levels of hunger and craving for pizza increased significantly after cue exposure (Table 4.2). By contrast, levels of fullness and desire-to-eat pizza were not significantly affected by cue exposure (Table 4.2).

Table 4.2 Within-subject *t*-tests, means, and standard deviations, for pre-exposure, and post-exposure, measures of cue reactivity

	Pre-exposure			Post-exposure		<i>t</i> -value and significance	
	<i>n</i>	Mean	SD	Mean	SD	<i>t</i>	<i>P</i>
Hunger (mm)	30	8.43	10.90	11.80	14.54	2.36	0.025*
Fullness (mm)	30	70.43	23.52	64.83	24.83	-1.02	0.317
Desire-to-eat pizza (mm)	30	12.27	16.74	16.53	21.54	1.454	0.157
Craving for pizza (mm)	30	6.07	8.97	14.60	21.58	2.62	0.014*
Pizza portion mm ² (kcal)	30	-	-	6852.12 (185.01)	5209.20 (140.64)	-	-

* denotes $p < 0.05$

4.4.4 Cue reactivity and everyday portion-size selection (Hypothesis 1)

After controlling for the relevant pre-exposure ratings, exposure to pizza was not found to stimulate greater feelings of hunger, desire-to-eat pizza, craving for pizza, or to significantly reduce feelings of fullness in individuals who recalled consuming larger everyday portion sizes (Table 4.3). However, after brief exposure to pizza, individuals who typically consume larger everyday portion sizes desired larger portions of pizza ($r = 0.521$, $p = 0.003$) (these results are not shown in a table here). Using the parameter estimates from a regression model used to predict desired pizza portion after cue exposure from everyday portion size, the number of Kcalories an individual with a small (2.89), medium (3.73), and large (4.80), average everyday portion size (calculated as the average value in each tertile of the data) might consume after cue exposure was predicted. As Figure 4.1 suggests the number of Kcalories in the portion of pizza selected by individuals who on average consume the largest everyday portion sizes more than doubled compared to the portion size selected by individuals who on average select small everyday portion sizes.

Table 4.3 Adjusted¹ parameter estimates from linear regression models of associations between the three measures of dietary behaviour (TFEQ-disinhibition score, DEBQ-restraint scores, and everyday portion size) and change in generalised measures of appetite (hunger and fullness), and change in appetite (craving and desire to eat) for pizza

	<i>n</i>	<i>B</i>	<i>SE</i>	<i>p</i>
DEBQ-restraint scores				
Change in hunger	30	1.589	2.000	0.434
Change in fullness	30	2.196	6.613	0.742
Change in desire-to-eat pizza	30	-5.806	3.084	0.070
Change in craving for pizza	30	-0.363	4.033	0.929
TFEQ				
Change in hunger	30	0.387	0.474	0.422
Change in fullness	30	-3.422	1.527	0.034*
Change in desire-to-eat pizza	30	1.337	0.767	0.093
Change in craving for pizza	30	2.324	0.897	0.015*
Everyday portion size				
Change in hunger	30	-1.198	1.836	0.520
Change in fullness	30	10.484	6.135	0.099
Change in desire-to-eat pizza	30	4.654	3.041	0.138
Change in craving for pizza	30	7.192	3.633	0.058

* denotes $p < 0.05$

¹ Adjusted for pre-exposure ratings

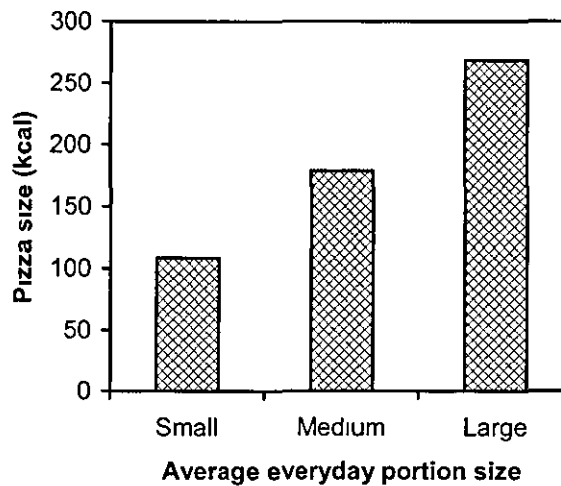


Figure 4.1 Predicted portion size of pizza in Kcalories (kcal) after cue exposure for individuals who report consuming small (2.89), medium (3.73), and large (4.80), everyday portion sizes estimated using the everyday portion-size selection parameter estimate ($B = 3096.01$) from the linear regression models for predicted portion size of pizza after cue exposure

4.4.5 Cue reactivity, dietary restraint, and TFEQ-disinhibition scores (Hypothesis 2)

After controlling for pre-exposure ratings, there was little evidence to suggest that change in hunger, fullness, desire to eat pizza, or craving for this food, were greater in individuals with higher restraint scores (Table 4.3). Furthermore, dietary restraint was unrelated to desired pizza-size ($r = 0.09$, $p = 0.648$) (these results are not shown in a table here), suggesting that dietary restraint status shares little relationship with food-cue reactivity.

With regards to the association between disinhibition and food-cue reactivity, although disinhibition scores were unrelated to changes in hunger and desire-to-eat pizza (Table 4.3), they were significantly associated with a reduction in feelings of fullness, and an increase in craving for pizza (Table 4.3), even after controlling for dietary restraint scores (both $p < 0.05$). Most importantly, these scores were also associated with the selection of larger pizza sizes after cue exposure ($r = 0.42$, $p =$

0.020) (these results are not shown in a table here) and this was even the case after statistically controlling for restraint status ($B = 645.52$, $SE = 270.85$, $p = 0.024$). Again, using the parameter estimates from a regression model used to predict ideal portion size for disinhibition scores and controlling for restraint scores, the number of Kcalories an individual with a low (3.8), medium (7.7), and high (11.3), disinhibition score (calculated as the average value in each tertile of the data) might desire after cue exposure were predicted. These are shown in Figure 4.2. Visual inspection of this figure suggests that an individual with a high disinhibition score would be likely to consume over 100kcal more than an individual with a low disinhibition score after exposure to a food cue while non-food deprived.

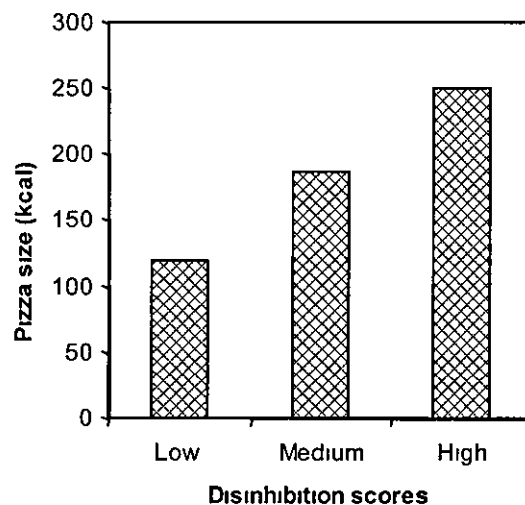


Figure 4.2 Predicted pizza size in Kcalories (kcal) after cue exposure for individuals with low (3.8), medium (7.7), and high (11.3), disinhibition scores estimated using the parameter estimate ($B = 649.69$) from linear regression models for pizza portion size⁹

⁹ In this model restraint scores were held at their mean value in the sample (2.81) and the parameter estimate associated with restraint scores was included ($B = 98.06$)

4.4.7 Awareness questionnaire

Following Experiment 2, in this experiment an awareness questionnaire was administered at the end of the study to determine the extent to which the results observed could be attributed to an awareness of the aims of the study. The responses to this questionnaire are summarised in Table 4.4. These responses suggest that the majority of the participants did not correctly guess the purpose of the study. Rather, most participants believed the cover story and suggested that the experiment was exploring the relationship between appetite and mood. However, a relatively small percentage (16.7%) of the participants guessed that appetite ratings were taken to explore the effect of exposure to pizza on appetite for this food. A similar percentage (20%) also guessed that portion-size selection was measured to determine the extent to which this exposure phase increased the amount of this food that participants wanted to eat. To determine the extent to which awareness of the study's interest in the effect of cue exposure on appetite ratings affected changes in these measures after cue exposure, regression analyses were used to explore associations between awareness of this aim and changes in subjective appetite. In this analysis the relevant pre-exposure ratings were controlled for by entering them as a covariate into the analysis. To determine the extent to which awareness of the study's interest in the effect of cue exposure on desired portion size of pizza affected portion-size selections, between-subject *t*-tests were used to compare desired portion size in aware, and non-aware, participants. All analyses provided little evidence to suggest that awareness of these aims predicted change in desired portion size of pizza, or changes in subjective appetite (all $p > 0.05$). Finally, to eliminate the possibility that awareness of the study aims did not account for the individual differences in cue reactivity observed, Pearson's correlation coefficients were calculated to determine the extent to which this awareness differed across the predictor variables (dietary restraint, dietary disinhibition, and everyday portion-size selection). Again, this provided little evidence to suggest that awareness differed across the dietary measures (all $p > 0.05$).

Table 4 4 Summary of responses to the awareness questionnaire All total are given in percentages

Question	Response (%)	
	Aware	Not aware
1 What do you think was the purpose of this experiment?	6 7	93 3
2. I asked you to rate your mood and appetite twice during the experiment. Do you know why?	16 7	83 3
3 In this experiment I asked you whether you would want to eat pizza and how much Do you know why?	20	80

4.4.6 Summary of results

The aim of this section is to provide a summary of the significant associations observed in this experiment. These associations are summarised in Table 4 5. Visual inspection of this table suggests that dietary restraint shared little association with any of the outcome variables. Rather, it suggests that dietary disinhibition, and a measure of everyday portion-size selection might be associated with greater food-cue reactivity. Specifically, dietary disinhibition was associated with a greater reduction in fullness, greater increase in craving for pizza, and a greater increase in desired portion size of this food. Likewise, the selection of larger everyday portion sizes was significantly associated with a greater change in desired portion size of pizza.

Table 4.5 Summary table to show the significant associations between the outcome variables and the predictor variables

	<i>Predictor variables</i>		
	Restraint	Disinhibition	Everyday portion size
<i>Outcome measures</i>			
Change in hunger			
Change in fullness		✓	
Change in desire-to-eat pizza			
Change in craving for pizza		✓	
Change in desired pizza portion		✓	✓

✓ Denotes where statistically significant interactions were observed

4.5 Discussion

This experiment predicted that individuals who show elevated sensitivity to food cues in the laboratory consume larger amounts of food within their everyday lives (Hypothesis 1). Consistent with this prediction, the results suggested that individuals who reported consuming larger everyday portion sizes selected the largest portions of pizza after cue exposure. Given that differences in awareness of the study aims, or in appetite for the cued food at the outset cannot explain these differences, it is important to consider potential explanations for this association. Perhaps the most obvious possibility is that those participants who reported consuming the largest portion sizes within their everyday lives were unaffected by cue exposure in this experiment and were simply behaving in a similar way in the laboratory as they do in their everyday lives by selecting the largest portion sizes. In other words, the fact that these individuals had been cued by pizza was perhaps irrelevant. Indeed, it is possible that these individuals would have selected these larger portion sizes of the cued food even in the absence of this cue exposure.

Notwithstanding the possibility offered above, there are at least two other potential explanations for this observed association. One possibility is that the tendency to consume larger amounts of food after food-cue exposure in fact contributes to

greater everyday portion-size selection, and for this reason an association was observed in this experiment between desired portion size of a cued food and everyday portion-size selection. Consistent with this possibility, there have been speculations that food-cue reactivity might be responsible for overeating (Wardle, 1990). A second explanation is that the consumption of larger everyday portion sizes *causes* greater sensitivity to food cues, and for this reason the association reported here exists. This might occur as greater food intake, which occurs for whatever reason, becomes paired with environmental cues in a form of Pavlovian conditioning (Pavlov, 1927). Following this, subsequent presentation of these cues might reinforce the desire to consume greater amounts. This explanation is based on the view taken by Jansen (1998) to explain food-cue reactivity in binge eaters. Jansen (1998) suggests that environmental cues become paired with consumption of larger amounts of food during a binge episode. Therefore, subsequent exposure to these cues reinforces binge eating. According to this explanation, the present findings could suggest that food-cue reactivity might not initially *cause* the consumption of larger everyday portion sizes, but rather might serve to maintain this tendency to consume larger amounts of food. Therefore, even according to this view, food-cue reactivity might be assumed to play an important role in overeating.

Notably, the basic premise of the two latter explanations offered here for the association between desired portion size of a cued food and everyday portion-size selections rely on the assumption that larger desired portion sizes of pizza were the *direct* result of food-cue exposure. However, by not observing desired portion-size selection in the absence of cue exposure, it is impossible to determine whether the selection observed after pizza-cue exposure was in fact a result of this cue exposure. For this reason, it is impossible to eliminate the initial possibility offered here suggesting that individuals were unaffected by cue exposure and were merely behaving in the same way they do outside the laboratory by selecting larger portion sizes. Some support for this possibility comes from the fact that these individuals were not found to report significantly greater changes in subjective appetite after cue exposure. Thus, suggesting that these individuals' appetite might not in fact have been affected by cue exposure. Given the importance of this issue for our understanding of the association between food-cue reactivity and everyday portion size, it is considered further in Experiment 4.

A secondary issue considered in this experiment was the extent to which food-cue reactivity is associated with measures of everyday dietary behaviour (dietary restraint and disinhibition) (Hypothesis 2). The results suggested that changes in subjective appetite, and desired pizza size, after cue exposure were not significantly associated with dietary-restraint status, despite the fact that restrained eaters were hungrier prior to cue exposure than unrestrained eaters. These findings are in part consistent with the results reported in Experiments 1 and 2. In both these experiments, dietary restraint scores were also found to share little association with food-cue reactivity. Yet, it is important to note that the results reported here differ slightly to those reported in Experiment 1. This is because, in Experiment 1, restrained eaters were also found to *inhibit* their food intake after food-cue exposure. Yet, the findings from the present experiment, and those presented in Experiment 2, have failed to replicate this finding.¹⁰ In these experiments, restrained and unrestrained eaters were not found to desire significantly different amounts after cue exposure irrespective of whether this was measured via *ad-lib* intake or using a measure of desired portion size. Notwithstanding this modest difference between the findings reported here and those reported in Experiment 1, the importance of the results from the present experiment is that again they dispute previous claims that dietary restraint presents a risk factor for greater reactivity to food cues.

Notably, in this thesis it was in fact hypothesised that food-cue reactivity might not be associated with an independent measure of dietary restraint (Hypothesis 2). This was because associations between dietary restraint and food-cue reactivity have been reported using a measure of restraint which conflates dietary restriction with disinhibited eating and weight fluctuation. For this reason, it was predicted that heightened sensitivity to the effects of food-cue exposure on appetite might be associated with a measure of disinhibition (Hypothesis 2). Consistent with this hypothesis, the present findings suggest that the TFEQ-disinhibition scale shares an association with food-cue reactivity. Notably, disinhibited eaters were found to experience greater food-cue reactivity irrespective of their restraint status.

¹⁰ Potential reasons for this were highlighted in Experiment 2 and will not be discussed further here

Restrained and unrestrained individuals with high disinhibition scores experienced a greater change in craving for pizza after cue exposure, and selected larger portions of this food.

Since individuals with high disinhibition scores were not found to differ in their appetite prior to cue exposure and did not have a greater awareness of the aims of the experiment than individuals with lower disinhibition scores, it seems reasonable to assume that greater reactivity observed in these individuals was in fact linked to their higher disinhibition scores. However, understanding why dietary disinhibition might be associated with greater food-cue reactivity is relatively difficult. This is because it is not entirely clear what the disinhibition scale measures. Originally, this scale was defined by Stunkard & Messick (1985) as a measure of 'disinhibition of control'. More recently, it has been referred to as an 'overeating scale' (Brunstrom *et al.*, 2005), a scale which assesses 'susceptibility to eating problems' (Westenhoefer *et al.*, 1994), and a measure of 'uncontrolled eating' (de Lauzon-Gullain, Basdevant, Romon, Karlsson, Borys, & Charles, 2006). Exploration of the items on the scale suggests that one possibility is that it measures a susceptibility to external triggers which promote food intake. These triggers might be social situations, emotional states, or external food cues. Therefore, individuals who obtain high scores on the disinhibition scale are likely to be unable to resist the temptation to eat offered by these cues. For individuals who obtain low scores on this scale some element of self-control must enable the temptation elicited by these external triggers to be resisted. Indeed, consistent with this, it has been suggested that even non-dieters are likely to exert some self-control over their food intake (Herman & Polivy, 2005). Based on this discussion, it is possible that in the present experiment, disinhibited eaters were unable to resist the temptation offered by the pizza cues, and for this reason reported greater subjective appetite for this food and desired larger portion sizes of it. By contrast, the individuals with lower disinhibition scores were more likely to have been able to exert some self control in this situation, and for this reason selected smaller portion sizes of the food.

4.6 Chapter summary

The experiment presented in this chapter considered the possibility that individuals who show elevated sensitivity to food cues in the laboratory consume larger amounts of food within their everyday lives. The results provided some evidence for an association between everyday portion-size selection and desired portion size of a cued food. However, in the absence of a measure of desired portion of pizza prior to cue exposure, one possibility is that those individuals who typically select the largest portion sizes within their everyday lives were unaffected by cue exposure and behaved similarly in the laboratory as they do in their everyday lives by selecting larger portion sizes. A secondary issue explored in this experiment was the extent to which food-cue reactivity is associated with measures of everyday dietary behaviour (dietary restraint and disinhibition). Taken together, the findings suggest that food-cue reactivity shares little association with successful dietary restraint, but is related to a measure of dietary disinhibition.

CHAPTER 5

FOOD-SPECIFIC REACTIVITY AND EVERYDAY PORTION-SIZE SELECTION

5.1 Chapter overview

This chapter discusses the fourth experiment in this thesis. This experiment was designed primarily to re-consider associations between food-cue reactivity and everyday portion-size selection. To improve upon the design used in Experiment 3, in this experiment desired portion-size selection was assessed in both a cued, and a non-cued, context. A secondary issue considered in this experiment was the extent to which food-cue reactivity is also associated with separate measures of dietary restraint and disinhibition. The remainder of this chapter presents details of the rationale, the methodology used, and analysis of the results, for this experiment.

5.2 Introduction

The primary aim of the preceding Experiment (Experiment 3, see Chapter 4) was to determine the extent to which greater food-cue reactivity is associated with the selection of larger everyday portion sizes. The findings of that experiment suggested that the consumption of larger average everyday portion sizes was associated with a desire to eat larger portions of pizza *after* exposure to this food. However, without knowledge of desired pizza size in the *absence* of cue exposure, it was impossible to conclude that the desire for a larger portion of pizza in individuals who reported selecting the largest everyday portion sizes was in fact a direct result of pizza-cue exposure. This is because it is possible that their desired portion of pizza after cue

exposure represented the portion that they would select even in the *absence* of pizza-cue exposure.

In Experiment 3, portion-size selection was not measured in a non-cued context following the conclusions drawn from Experiments 1 and 2. In these experiments, *ad-lib* food intake was explored in the absence of cue exposure (no-cue condition) and after three-minute food-cue exposure (food-cue condition). However, it was suspected that the no-cue condition might in fact have become a 'cued condition' in the *ad-lib* intake phase. This is because exposure to the sight and smell of food (as well as perhaps the taste of food) in this phase might have served to cue appetite for pizza. In Experiment 3, it was assumed that participants would be required to view the pizza to judge their desired portion size even in a presumably non-cued context. Thus, following from observations in Experiments 1 and 2 it was suspected that the sight and smell of the pizza in this apparent no-cue condition would be sufficient to cue appetite for this food, thus eliciting another 'cued' condition. On this basis, it was decided that a 'no-cue' condition would not be included in Experiment 3.

However, one possibility which was not considered in this experiment was that rather than viewing the food itself in order to indicate a desired portion-size in a 'no-cue condition,' participants could in fact view a model of this food. Indeed, the purpose of viewing the food is to give the participant an idea of its basic attributes. However, this could in fact be achieved using a food model. The advantage of this would be that the model would not elicit an olfactory cue, and if it was distinct from the food itself except for the basic characteristics, it would also not provide a strong visual cue for this food. Thus, using such models, it would be possible to explore portion-size selections in the absence of food-cue exposure. Following this reasoning, in Experiment 4, it was decided that a green cardboard model of pizza would be used to obtain a measure of desired pizza in the absence of exposure to this food. This model simply conveyed the base/crust of the pizza and gave some indication of the amount of topping on the pizza (see Appendix E for a picture of this). This measure of pizza size in the non-cued context could then be compared to desired pizza size after cue exposure, and the effect of pizza-cue exposure on portion-size selection of this food could be determined. Using this improved measure of portion-size selection and conventional measures of subjective appetite

used in Experiments 1 and 2, this experiment sought to re-explore associations between food-cue reactivity and everyday portion size. Again, it was hypothesised that those individuals who select larger everyday portions will experience greater sensitivity to food cues (Hypothesis 1). As a secondary issue, this experiment also explored associations between food-cue reactivity and measures of everyday dietary behaviour (dietary restraint and disinhibition). Again, it was hypothesised that food-cue reactivity would be more closely associated with dietary disinhibition rather than restraint status (Hypothesis 2). Specifically, it was hypothesised that those individuals with high disinhibition scores would experience greater cue reactivity than those individuals with lower disinhibition scores. By contrast, it was expected that restrained eaters would not experience any greater cue reactivity than unrestrained eaters.'

As part of the present experiment, it was desirable to explore the extent to which any differences in motivation to eat across the three dietary measures (everyday portion-size selection, dietary restraint, and disinhibition) were specific to the cued food. For example, it was useful to determine the extent to which those individuals who select larger everyday portions relative to those who select smaller everyday portion sizes experience a greater motivation to eat the cued food, but do not experience a greater motivation to eat the non-cued foods. As outlined previously in Chapters 2 and 3, specificity can be explored by determining the effect of food-cue exposure on measures of cue reactivity for both the cued food, and for non-cued foods. Thus, in Experiment 4, desired portion-size selections and subjective appetite (desire to eat and craving) for pizza, and several other foods (peanuts, chips, garlic bread, chocolate, and chocolate cake), were assessed after brief exposure to the sight and smell of pizza. The non-cued foods were selected on the basis that they differed in the extent to which they would be served alongside the cued food (pizza) within a meal. To ensure that a non-cued measure of portion-size selections of these food was obtained, participants indicated their portion selections both before and after cue exposure also using models of these foods (see Appendix E for pictures of these foods).

In previous cue reactivity studies, including those presented in this thesis, little consideration has been given to the potential effect that an individual's liking for a cued food has on their motivation to eat this food. This is surprising given that an individual's predilection towards particular foods must influence the effect that exposure to these food has on these individuals. For this reason, in the present experiment participants' liking for the cued food, and their liking for the non-cued foods, was measured. This was then controlled for in the analyses exploring associations between the three dietary variables (everyday portion-size selection, dietary restraint, and disinhibition) and measures of food-cue reactivity. By doing this, the possibility that any association observed could be attributed to differences in liking for the test food could be eliminated.

In summary, using an improved methodology, Experiment 4 re-considered the association between food-cue reactivity and the selection of larger everyday portion sizes. It was hypothesised that those individuals who select larger everyday portions will experience greater sensitivity to food cues (Hypothesis 1). As a secondary issue, this experiment also considered the relationships between food-cue reactivity and measures of everyday dietary behaviour (dietary restraint and disinhibition). Again, it was hypothesised that food-cue reactivity would be more closely associated with dietary disinhibition rather than restraint status (Hypothesis 2). Unlike the methodology used in Experiment 3, the methodology used in this experiment allowed an assessment of the direct effect of cue exposure on portion-size selection by observing portion-size selection in a cued, and non-cued, context.

5.3 Method

5.3.1 Overview

Again in this experiment after access to a buffet-style lunch participants were exposed to the sight and smell of pizza for three minutes. Immediately before and after this, they rated their subjective appetite for the cued (pizza), and non-cued, foods (chips, garlic bread, peanuts, chocolate and chocolate cake), and indicated

their desired portion size of these foods at that moment in time. A key feature of this methodology was that a measure of subjective appetite for the cued, and non-cued, foods was also obtained before and after participants' pre-exposure (baseline) portion-size selections. These measures were included because it was desirable to ensure that the food models used to make portion-size selections did not cue appetite for these foods. Thus, this could be assessed by comparing subjective appetite from before to after cue exposure.

The questionnaire phase in this experiment was split across the experiment. Participants reported their everyday portion-size selections at the outset prior to the buffet-style lunch, and completed the DEBQ-restraint, TFEQ-disinhibition questionnaire, and awareness questionnaire in the final stages of the experiment. The reason the measure of average everyday portion size selection was obtained at the outset in this experiment was to address the possibility that portion-size selections of the cued, and non-cued, foods made throughout the experiment influences participants' recall of their everyday portion-size selections.

5.3.2 Design

The design employed in this experiment was a within-subject design. Participants provided a measure of subjective appetite, and portion-size selections, for the cued, and non-cued, foods both before and after food-cue exposure.

5.3.3 Participants

Thirty participants were recruited from the population of female students at Loughborough University (UK) (mean age = 20.57, SD = 2.112) (mean BMI = 22.48, SD = 2.19). Participants were recruited via email and received seven pounds (sterling) for their participation.

5.3.4 Measures

1. Cue reactivity

Hunger and fullness, and craving for, and desire to eat, the cued (pizza) and non-cued foods (chips, garlic bread, peanuts, chocolate, and chocolate cake) were assessed using scales identical to those used in Experiment 1 (see Chapter 3)

Desired portion-size estimates were made for each of the non-cued foods before and after pizza-cue exposure using a model of this food. For the cued food, pizza, this model was only used before cue exposure. This is because after cue exposure participants were able to use the pizza itself in order to judge their desired portion size. These models and details of how portion-size selections were made and how they were measured are described separately for each food below (For pictures of these models see Appendix E)

Food models

Pizza was represented using a cardboard model of pizza (150mm x 130mm x 32mm). This was identical in shape and size to the slice presented during cue exposure. Participants were told that this model represented a cheese and tomato pizza. Using this model as a reference, the participants were asked to select their desired portion of pizza at that moment in time. They indicated this using the sheet of card described in Chapter 4. The area of the selected portion size was then calculated. This sheet of card was also used to measure desired pizza size after cue exposure. However, at this stage the participants were able to use the pizza presented during the exposure phase as a reference rather than the cardboard model.

Chocolate was represented using a black and white photocopy of a 650g bar of Cadbury's chocolate, which merely depicted the grid-like pattern of a chocolate bar. For this food, participants were simply asked to indicate the number of pieces of chocolate they would like to eat at that time.

Peanuts were represented using silver metal hardware nuts which were presented to participants in a bowl. The participants were asked to place their desired portion size in a smaller bowl which was later weighed.

Chips were represented using 40mm pieces of wood doweling. Participants were asked to place their desired portion size on a plate and the amount selected was weighed.

Garlic bread was represented by a hand-drawn bird's eye view and side view of this food. Portion-size selection of this food was calculated by measuring the area of the portion selected on the side-view version.

Chocolate cake was represented using a circular piece of foam (circumference 30cm, depth 10cm). Again, portion-size selection of this food was calculated by measuring the area of the portion selected.

2 Everyday portion size

Everyday portion-size selections were assessed using the same method as in Experiment 3. However, in this experiment participants were asked to recall their typical portion sizes for a greater number of foods. These included the foods used in Experiment 3 (pasta, cornflakes, chocolate cake, potatoes, baked beans, lasagne, spaghetti bolognese, chips, and cheesecake), and several new foods (sponge pudding, roast beef, battered fish, carrots, fruit salad, and quiche). By broadening the range, and number, of foods that comprised the measure of participant's average everyday portion size, it was assumed that this measure would provide a more valid assessment of participant's everyday portion size. This is because increasing the number of foods comprising the measure of average measure of everyday portion results in a more accurate reflection of a participants everyday portion size.

3 Dietary restraint and disinhibited eating

Again, these dietary behaviours were assessed using the restraint section of the Dutch Eating Behaviour Questionnaire (DEBQ; van Strien *et al*, 1986) and the disinhibition section of the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985).

4 Awareness Questionnaire

An awareness questionnaire was issued at the end of the experiment to ensure that participants were not aware of the aims of this experiment. This questionnaire asked

i) what do you think was the purpose of this experiment? ii) I asked you to rate your mood and appetite at three points during the experiment. Do you know why? iii) In this experiment I asked you to indicate the amounts of various foods that you would like to eat at that time. Do you know why?, iv) I did expect you to want to eat greater amounts of the food than you might normally do at one time point. Which time point was this? (first or second), v) I expected you to want to eat greater amounts of food than you might normally do at the second time point. Which food (s)? These questions were displayed on separate sheets of paper and participants were instructed to turn to the next page only when their answer to the previous question was complete.

5.3.5 Procedure

Before arriving to be tested the participants were told that the aim of the experiment was to explore the relationship between 'appetite and mood.' They were also told that they would have to rate their mood throughout the experiment, that they would be asked to offer an opinion on various foods, and that they would receive a buffet-style lunch.

Participants were tested between 11am and 3pm. All were instructed to refrain from eating for three hours prior to the onset of the experiment. On arrival, participants provided a measure of their everyday portion sizes. They were then presented with a buffet lunch which comprised the same items as Experiments 2 and 3, and were asked to eat until they felt 'comfortably full.' After lunch, participants provided a set of appetite ratings which served as a baseline measure of subjective appetite prior to pre-exposure portion-size selections. Immediately after completing these ratings, participants were invited to make their pre-exposure (baseline) portion-size selections. Following this, a second set of appetite ratings were taken. These measures allowed exploration of the effects of making portion-size selections on appetite, and also served as a pre-exposure (baseline) measure of subjective appetite. Consistent with the cover story, these subjective measures of appetite also included a number of ratings relating to the participant's current mood.

The next phase was the cue exposure stage. In this phase, participants were exposed to the sight and smell of cooked pizza for three minutes. The pizza was presented in a rectangle slice, and weighed 300g (810 kcal). It was placed on a table directly in front of the participant. During this exposure phase, participants were instructed to sit and wait until the experimenter returned. After exposure, the participants provided post-exposure portion-size selections and appetite ratings. After this, the participants rated their liking for the cued and non-cued foods, and completed measures of dietary restraint and disinhibited eating. Finally, participants completed an awareness questionnaire.

5.3.6 Data Analysis

In Experiment 4, a series of cue reactivity measures were obtained before and after pizza-cue exposure. These included general measures of subjective appetite (hunger and fullness), measures of subjective appetite (desire to eat and craving) for the cued and non-cued foods, and measures of desired portion size of these foods. As in Experiment 3, preliminary analyses were used to assess the descriptive statistics (means and SD's) for these measures and to assess the general effect of cue exposure on appetite by comparing pre- and post-cue exposure measures using within-subjects t-tests. In addition to this, preliminary analyses were also conducted to ensure that the use of food models for the pre-exposure measures provided a non-cued measure of participants' desired portion sizes. To do this, within-subject t-tests were used to compare general subjective appetite (hunger and fullness) and subjective appetite (desire to eat and craving) for the cued, and non-cued, foods. If these food models were providing a non-cued measure, there would be little change in subjective appetite. Finally, as part of the preliminary analyses, descriptive statistics for participant characteristics (dietary restraint, disinhibition, and everyday portion-size selection) were produced and a series of Pearson Correlation Coefficients were calculated to assess the associations between each of these variables.

Following the various preliminary analyses for each of the outcome measures (appetite ratings and desired portion sizes), a change score was derived from the

difference between the measure of reactivity before and after cue exposure. To determine the extent to which these change scores were associated with average everyday portion size, dietary restraint, and disinhibition scores, separate regression analyses were used. In each of these regression models liking for the food of interest, and the corresponding pre-exposure rating for each of the change scores, was controlled for statistically by entering it as a covariate into the regression model. To determine the extent to which any differences in subjective appetite across disinhibition scores were modulated by restraint status in these analyses, a second series of regression models were conducted for disinhibition scores which controlled for restraint status by entering it as a covariate into the regression model.

5.4 Results

5.4.1 Participant characteristics

Table 5.1 Means and standard deviations for participant characteristics

	<i>n</i>	Mean	SD
<i>Characteristic</i>			
BMI	30	22.48	2.19
TFEQ-disinhibition score	30	7.13	3.46
DEBQ-restraint score	30	2.82	0.82
Everyday portion size	30	4.19	0.83

Means and SD's for each of the participant characteristics are summarised in Table 5.1. It was desirable to determine the extent to which the dietary measures (everyday portion size, dietary restraint, and disinhibition) were associated with each other. Thus, a series of Pearson's correlation coefficients were calculated. Restrained eaters had significantly higher disinhibition scores ($r = 0.531$, $p = 0.003$), but did not select significantly larger everyday portion sizes ($r = -0.302$, $p = 0.101$). Contrary to the findings from Experiment 3, there was little evidence to suggest that individuals with higher disinhibition scores select significantly larger everyday portion sizes ($r = 0.005$, $p = 0.979$).

5.4.2 Baseline measures

Initially it was desirable to establish that there were no significant differences in hunger or fullness, subjective appetite for the test foods, or portion-size selections across the three dietary measures immediately prior to cue exposure. Pearson's correlation coefficients were calculated for this purpose and provided little evidence to suggest that any of these outcome measures differed significantly across the three dietary measures (all $p > 0.05$).

5.4.3 Descriptive statistics for measures of cue reactivity

Initially, it was desirable to explore the descriptive statistics for the measures of cue reactivity before and after cue exposure. The means and standard deviations for changes in subjective appetite and for portion-size selections for the cued and non-cued foods are therefore summarised in Table 5.2. The results of within-subject *t*-tests used to compare the pre- and post-exposure measures are also presented alongside these descriptive statistics. The results suggest that pizza-cue exposure significantly increased participants' ratings of hunger, craving for pizza, and desire to eat this food, and significantly decreased their reported fullness (Table 5.2). It also suggests that it increased participants' craving for peanuts and chips (Table 5.2). By contrast, there was little evidence to suggest that pizza-cue exposure significantly stimulated the selection of a larger portion of pizza, or of the non-cued foods (Table 5.2).

Table 5.2 Within-subject *t*-tests, means, and standard deviations, for pre-exposure and post-exposure subjective appetite and portion-size selections

	Pre-exposure			Post-exposure		<i>t</i> -value and significance	
	<i>n</i>	Mean	SD	Mean	SD	<i>t</i>	<i>p</i>
Hunger	30	11.18	11.80	19.68	17.38	3.39	0.002*
Fullness	30	73.46	17.78	66.86	21.84	-3.06	0.005*
<i>Desire-to-eat</i>							
Pizza	30	13.60	16.79	32.47	31.68	3.83	0.001*
Chocolate	30	32.00	28.08	26.07	24.90	-1.52	0.140
Peanuts	30	9.80	13.56	9.27	14.29	-0.25	0.805
Chips	30	10.23	14.12	9.20	9.53	-0.48	0.635
Garlic bread	30	10.90	16.68	12.93	21.90	0.63	0.531
Chocolate cake	30	25.47	26.11	27.57	25.50	0.65	0.522
<i>Craving</i>							
Pizza	30	14.07	23.03	33.57	31.05	3.18	0.004*
Chocolate	30	23.87	25.91	26.60	24.42	0.94	0.357
Peanuts	30	4.93	8.32	10.13	16.97	2.55	0.016*
Chips	30	5.80	8.06	10.57	15.84	2.36	0.025*
Garlic bread	30	6.80	14.83	7.63	18.05	0.33	0.741
Chocolate cake	30	18.93	24.31	22.23	23.81	1.10	0.279
<i>Desired portion size</i>							
Pizza (mm ²)	30	5037.70	6817.57	7153.55	6431.18	1.66	0.107
Chocolate (pieces)	30	5.23	4.31	4.63	4.45	-0.84	0.404
Peanuts (g)	30	27.53	38.99	22.07	43.11	-0.96	0.343
Chips (g)	30	15.36	18.98	16.49	24.00	0.36	0.719
Garlic bread (mm ²)	30	2620.00	3947.01	3000.00	5499.09	0.70	0.489
Chocolate cake (mm ²)	30	2251.70	1850.98	1674.40	3947.01	-0.85	0.404

* denotes $p < 0.05$

5.4.4 Effect of food models on subjective appetite

To substantiate the claim that the food models used in this experiment provided a non-cued measure of participants' desired portion sizes, the effect of these models on appetite was assessed by comparing ratings taken from before, to after, initial exposure to these models (i.e., when participants were indicating their pre-exposure desired portion sizes). These analyses suggested that being exposed to the food models significantly reduced hunger ($t = -3.78$, $df = 29$, $p = 0.001$), and did not significantly affect any of the other appetite ratings (all $p > 0.05$). This suggests that the food models did not affect appetite, and thereby can be accepted as providing a non-cued measure of portion-size selection.

5.4.5 Cue reactivity and everyday portion size (Hypothesis 1)

Average everyday portion-size selection was not significantly associated with a greater change in general measures of subjective appetite (hunger and fullness), or with a greater change in appetite (desire-to-eat and craving) for pizza, or for the non-cued foods (all $p > 0.05$). Furthermore, there was little evidence to suggest that changes in desired portion size of pizza, or of the non-cued foods differed significantly across average everyday portion sizes (all $p > 0.05$).

5.4.6 Cue reactivity, dietary restraint, and disinhibition scores (Hypothesis 2)

Changes in reported hunger and fullness were not found to differ significantly across restraint scores after pizza-cue exposure (Table 5.3). Furthermore, restrained eaters were not found to report a greater change in subjective appetite (desire to eat and craving), or portion-size selection for pizza, or for the several of the non-cued foods, (chips, garlic bread, peanuts, and chocolate cake) after cue exposure (Table 5.3). However, somewhat unexpectedly, restrained eaters were found to experience a greater change in desire-to-eat chocolate (Table 5.3). Yet, visual inspection of the data for this measure identified an outlier. This data point represents a change in

desire-to-eat chocolate which is 3.32 standard deviations below the mean. With this outlier removed, the association between change in desire-to-eat chocolate and restraint scores was not statistically significant ($B = 6.74$, $SE = 3.28$, $p = 0.050$).

For individuals with high disinhibition scores, exposure to pizza stimulated a significantly greater change in hunger, but failed to significantly reduce levels of fullness (Table 5.3). It also failed to stimulate a greater desire-to eat pizza, greater craving for this food, or a larger desired portion size in these individuals (Table 5.3). For the majority of the non-cued foods, subjective appetite and desired portion sizes also did not differ across disinhibition scores (Table 5.3). However, individuals with high disinhibition scores did experience a greater change in desire-to-eat chocolate (Table 5.3), even after removal of the outlier associated with this variable (see above) ($B = 1.93$, $SE = 0.81$, $p = 0.025$). Yet, importantly, this association failed to reach statistical significance after controlling statistically for dietary-restraint status both with ($B = 1.48$, $SE = 1.20$, $p = 0.190$), and without, the outlier removed from the data set ($B = 1.44$, $SE = 0.93$, $p = 0.134$). This suggests that disinhibition scores were not independently associated with change in desire-to-eat chocolate, and that the variance in this variable is in fact explained by dietary-restraint status which is confounding the effect of the disinhibition scores.

Individuals with high disinhibition scores also experienced a greater change in desired portion-size selections of chocolate cake (Table 5.3). However, visual inspection of this data again revealed an outlier. The change in portion-size selection experienced by this participant was 4.35 standard deviations below the mean. For this reason this participant's data was removed from this analysis. Yet, even after removing this outlier, the associations between disinhibition scores and desired portion size remained statistically significant ($B = 118.77$, $SE = 50.65$, $p = 0.027$). This was even the case after controlling statistically for dietary-restraint status ($B = 125.82$, $SE = 58.87$, $p = 0.043$).

Table 5.3 Adjusted¹ parameter estimates from linear regression models of associations between the two measures of dietary behaviour (TFEQ-disinhibition score, and DEBQ-restraint scores) and the change in measures of cue reactivity (subjective appetite and desired portion size)

		TFEQ-disinhibition scores			DEBQ_restraint scores		
	<i>n</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>
<i>Changes</i>							
Hunger	30	4.05	3.02	0.191	1.51	0.68	0.034*
Fullness	30	-2.82	3.03	0.360	-0.88	0.67	0.205
<i>Desire-to-eat</i>							
Pizza	30	10.24	6.10	0.105	2.34	1.55	0.144
Chocolate	30	11.41	4.99	0.030*	2.20	0.96	0.030*
Peanuts	30	-1.01	2.92	0.733	-0.06	0.75	0.939
Chips	30	1.38	3.61	0.705	0.54	0.82	0.511
Garlic bread	30	-3.53	4.30	0.419	-0.48	1.07	0.659
Chocolate cake	30	-0.28	7.78	0.718	1.34	1.74	0.450
<i>Craving</i>							
Pizza	30	9.93	6.66	0.148	2.75	1.68	0.112
Chocolate	30	4.68	4.41	0.180	1.24	1.11	0.278
Peanuts	30	3.14	2.24	0.173	0.26	0.58	0.654
Chips	30	0.82	2.59	0.755	-0.48	0.59	0.417
Garlic bread	30	1.00	3.52	0.779	-0.31	0.850	0.718
Chocolate cake	30	6.24	4.37	0.165	1.73	0.97	0.086
<i>Desired portion size</i>							
Pizza (mm ²)	30	1114.45	1324.60	0.408	353.27	332.87	0.298
Chocolate (pieces)	30	-0.12	0.99	0.906	-0.24	0.25	0.340
Peanuts (g)	30	3.45	7.16	0.634	-0.81	1.83	0.661
Chips (g)	30	-0.50	4.07	0.903	-0.66	0.92	0.480
Garlic bread (mm ²)	30	221.89	684.41	0.748	195.50	160.38	0.234
Chocolate cake	30	536.43	318.06	0.104	148.87	70.39	0.044*
(mm ²)							

* denotes $p < 0.05$

¹ Adjusted for relevant pre-exposure rating, and for liking for that food (in models for specific foods)

5.4.7 Awareness Questionnaire

Following the previous experiments demand awareness was assessed in the final stage of this experiment. This assessment suggested that none of the participants correctly guessed the purpose of this experiment (Table 5.4). However, when prompted with particular questions about specific elements of the experiment, some participants (30%) did provide responses which suggested that they were aware of the experiments interest in changes in subjective appetite after cue exposure (Table 5.4, question 2). To determine the extent to which this awareness affected the changes in subjective appetite, a series of regression analyses were conducted to explore associations between these changes and awareness of this aim. In these analyses, pre-exposure rating was controlled for statistically by entering it into the analysis as a covariate, and where appropriate liking for the food was also controlled for. These analyses provided no evidence to suggest that awareness of the interest in the effect of cue exposure on subjective appetite affected the changes in these measures (all associations $p > 0.05$). In addition to this analysis, it was also desirable to determine the extent to which awareness of this aim differed across the dietary measures. Thus, a series of between-subject t-tests were used to assess this. These provided little evidence of statistically significant associations (all $p > 0.05$).

Although the responses to the awareness questionnaire suggested that only a small number of participants were aware of the interest in the effect of cue exposure on portion-size selection, when explicitly told that participants were expected to select larger portion sizes in this experiment at the second time point (i.e. after cue exposure), almost half the participants guessed that portion size of pizza was expected to increase. However, after controlling for liking for pizza and pre-exposure portion-size selection of this food, there was little evidence to suggest that this awareness predicted the change in desired pizza size observed after cue exposure. Furthermore, this awareness did not differ significantly across the dietary measures (everyday portion size, dietary restraint, and disinhibition) (all $p > 0.05$).

Table 5 4 Summary of responses to the awareness questionnaire All total are given in percentages

Question	Response (%)	
	Aware	Not aware
1. What do you think was the purpose of this experiment?	0	100
2 I asked you to rate your mood and appetite twice during the experiment Do you know why?	30	70
3. In this experiment I asked you to indicate the amounts of various foods that you would like to eat at that time Do you know why?	13 3	86 7
4. I did expect you to want to eat greater amounts of the food than you might normally do at one time point. Which time point was this? (first or second)	46	54
5 I expected you to want to eat greater amounts of food than you might normally do at the second time point Which food (s)?	46	54

5.5 Discussion

Experiment 4 primarily sought to explore associations between food-cue reactivity and everyday portion-size selection by considering differences in portion-size selection in a cued, and a non-cued, context. Given that that the food models used in the non-cued context did not stimulate appetite, these measures can be confidently regarded as a non-cued assessment of portion-size selection. However, despite the merits of the methodology employed here, the results provided little evidence of a significant association between change in desired portion size of the cued, and non-cued, foods and reported everyday portion size-selections. This suggests that cue exposure had a similar effect on the desired portion size of the cued, and non-cued, foods irrespective of participants' everyday portion-size selections.

In Experiment 3, the *total* desired portion-size selection observed in the cued context was significantly associated with everyday portion-size selections, such that those individuals who typically selected the largest everyday portion sizes also

selected the largest portion sizes of the cued food. However, one concern was that elevated portion-size selection in these individuals was not a result of the stimulation generated by the pizza cue, but was rather a reflection of their general tendency to select larger portion sizes. As a result of this concern, in the present experiment measures of desired portion-size selection were obtained in a cued, and non-cued, context. Yet, as suggested above, this provided little evidence to suggest that cue exposure had a significantly different effect on portion-size selection for individuals who typically select larger everyday portion sizes relative to those who select smaller everyday portion sizes.

Despite the findings from the present experiment, and the concern relating to the finding from Experiment 3, there is still reason to suspect that there might be an association between food-cue reactivity and everyday portion-size selection. This is because, firstly, the present experiment has provided evidence to contradict the possibility that the association between desired portion size of a cued food and everyday portion-size selection observed in Experiment 3 was merely a reflection of individuals' general tendency to select larger portion sizes, and had little to do with the fact that they had just been exposed to a food cue. Indeed, in the present experiment there was little evidence to suggest that measures of desired portion size observed in the non-cued contexts were associated with reported everyday portion-size selections. Yet, if individuals who typically select the largest everyday portion sizes have a general predilection to select larger portion sizes within the context the laboratory, they would have also been expected to select larger desired portion sizes even in the non-cued context. The second reason to be cautious about dismissing an association between food-cue reactivity and everyday portion-size selection relates to the reliability of the findings in the cued context in the present experiment. To recap, in Experiment 3, desired portion sizes of the cued food in this context were significantly associated with everyday portion-size selections. However, in the present study, a post-hoc regression analysis of the total desired portion sizes in the cued context failed to reveal this significant association ($p = 0.264$).

The reason for the discrepancy between the findings from the present study and those reported in Experiment 3 is unclear. However, one possibility is that it is the result of methodological differences between the two studies. One methodological

difference in this experiment relative to Experiment 3 was that the measure of everyday portion size was obtained at the outset prior to the buffet lunch, rather than in the final stages of the experiment as in Experiment 3. Consequently, in the present study participants recalled everyday portion size after three-hour food deprivation when they would presumably have a greater motivation to eat. By contrast, in Experiment 3, participants recalled their everyday portion size while satiated. This might be an important difference given that previous studies have suggested that levels of satiety can influence participants' recall of their everyday portion-size selection (Beasley, Hackett, Maxwell, & Stevenson, 2004). Indeed, there was a substantial difference in recalled everyday portion-size selections between Experiments 3 and 4. In this experiment average everyday portion-size selection was 4.19, whilst in Experiment 3 it was 5.67. The reason for changing the order of the procedure in the present experiment, such that participants recalled their everyday portion sizes at the outset, was to eliminate any effects of the experimental procedure on recall of everyday portion-size selection. In Experiment 5, these issues were addressed by assessing everyday portion-size selections immediately after the buffet lunch. This ensured that participants were satiated prior to this recall and eliminated any effects of the experimental procedure.

As in Experiment 3, a secondary issue considered in this study was the associations between food-cue reactivity and measures of everyday dietary behaviour (dietary restraint and dietary disinhibition). Again, the results provided little evidence to suggest that restrained eaters were more reactive to food cues than unrestrained eaters. These individuals were not found to experience a greater change in subjective appetite, or portion-size selection, for pizza. Furthermore, in the most part, they were not found to experience a greater change in appetite (subjective appetite and portion-size selection) for the non-cued foods. One exception to this was that dietary restraint was found to be associated with a greater change in desire-to-eat chocolate. However, this association was no longer statistically significant after the removal of an outlier associated with this measure. Since this failure to observe a difference in food-cue reactivity across restrained and unrestrained eaters cannot be attributed to differences in awareness of the aims of the experiment, differences in pre-exposure appetite, or liking for the test foods, this finding can be

taken as further support for the proposition that food-cue reactivity shares little relationship with dietary-restraint status.

With regards to dietary disinhibition, in this study, individuals with high disinhibition scores did not experience a greater change in subjective appetite for pizza after food-cue exposure, or a greater change in portion size-selection of this food. However, there were found to experience a greater change in appetite for at least two of the non-cued foods (chocolate and chocolate cake). Given that appetite for the other non-cued foods did not increase after cue exposure, and that there is no theoretical justification for appetite for these specific foods to be stimulated by exposure to pizza, one possibility is that they were the result of a Type I error.

In Experiments 1 and 3 presented in this thesis, measures of cue reactivity were found to be associated with dietary disinhibition. After cue exposure, individuals with higher disinhibition scores reported a greater change in appetite for the cued food (Experiments 1 and 3), and selected larger portion sizes of this food (Experiment 3). Therefore, it is somewhat surprising that the present findings fail to provide support for an association between measures of food-cue reactivity and this dietary disinhibition. However, notably, Experiment 2 also failed to provide evidence for such an association. One possible explanation for the discrepancy in the findings reported in separate experiments presented in this thesis is that where associations are found, another variable is accounting for these relationships. After considering the evidence from all six experiments presented in this thesis, Chapter 8 will discuss this possibility further.

5.6 Chapter summary

This chapter presented the findings from the fourth experiment conducted for this thesis. This experiment was designed to re-consider the associations between food-cue reactivity and everyday portion size using an improved design to that employed in Experiment 3. This design allowed desired portion size (and subjective appetite) to be assessed in a cued, and a non-cued, context. The results from this experiment provided little evidence to support the hypothesis that food-cue reactivity plays an

important role in everyday portion-size selection. A secondary issue considered in experiment 4 was the extent to which food-cue reactivity is also associated with measures of everyday dietary behaviour (dietary restraint and disinhibition). However, the results also provided little evidence to suggest that food-cue reactivity shares an association with either dietary-restraint status, or with disinhibition scores.

CHAPTER 6

FOOD-CUE REACTIVITY AND BMI

6.1 Chapter overview

This chapter presents the methods and findings from Experiment 5. The primary aim of this experiment was to assess the implications of being overweight for food-cue reactivity. To do this, measures of cue reactivity were compared across overweight, and non-overweight, individuals. As a secondary issue, this experiment also sought to explore associations between measures of food-cue reactivity and everyday portion-size selections and everyday dietary behaviour (dietary restraint and disinhibition). The remainder of this chapter presents details of the rationale for this experiment, the methodology used, and analysis of the results.

6.1 Introduction

After providing some evidence to suggest that heightened reactivity to food cues might be associated with the selection of larger everyday portion sizes (Experiment 3), the next step was to consider the potential influence of food-cue reactivity on BMI. In the 1970's, it was suggested that overweight individuals might be more susceptible to the stimulatory effects of environmental food cues than non-overweight individuals. For example, several studies suggested that cues, such as the time of day, the taste of food, the availability and accessibility of food, and the prominence of food items, had a greater impact on the intake of overweight, relative to non-overweight, individuals (see Chapter 2). These findings were explained by Schachter's (1968, 1971) externality hypothesis. In this hypothesis, Schachter (1968, 1971) suggested that overweight individuals eat primarily in response to immediate external cues associated with food, and ignore internal physiological stimuli signalling hunger and fullness. By contrast, he suggested that the eating

behaviour of normal-weight individuals is governed primarily by internal physiological signals of energy depletion

However, Schachter's (1968, 1971) externality hypothesis came under severe criticism. In the most part, this was because overweight individuals' greater sensitivity to external cues was not reported consistently across studies (e.g., Rodin, *et al.*, 1976, Rodin, *et al.*, 1977). As a result of this, it was suggested that the externality hypothesis presented a rather simplistic account of the differences in eating behaviour between overweight, and non-overweight, individuals (Rodin, 1981). Prior to this criticism, Nisbett (1972) had already suggested that differences in external eating behaviour were in fact mediated by dietary restraint, rather than by BMI. According to Nisbett's (1972) hypothesis, individuals who have a tendency to restrict their dietary intake experienced a greater motivation to eat after exposure to a food cue. Nisbett (1972) explained greater sensitivity to food cues previously observed in overweight individuals by suggesting that these individuals were more likely to engage in dietary restraint by dint of the fact that society places pressure on individuals to adhere to a slim ideal. Therefore, Nisbett (1972) suggested that by restricting their dietary intake, overweight individuals were often found to be more sensitive to food cues than non-overweight individuals (see Chapter 2). However, contrary to Nisbett's (1972) hypothesis, the findings presented in this thesis suggest that dietary restraint per se is not the critical factor determining individuals' susceptibility to the stimulatory effects of a food cue. Therefore, one possibility is that Schachter (1968, 1971) was indeed correct, and that being overweight might be an important factor for sensitivity to food cues. The reason studies exploring this possibility have failed to consistently report associations between sensitivity to external cues and being overweight might in fact have been a result of methodological limitations.

More recently, Jansen *et al.* (2003) have used a more modern food-cue reactivity paradigm (similar to that used in experiments presented in this thesis) to compare sensitivity to food cues in overweight, and non-overweight, children. By doing this, the authors found that overweight children consumed greater amounts after food-cue exposure than they consumed in the absence of this exposure. By contrast, they found that non-overweight children consumed greater amounts in the no-cue,

relative to the food-cue, condition. Drawing on previous theorising by the primary author (Jansen, 1998), Jansen *et al* (2003) suggested that the reason they observed greater food intake in overweight children after cue exposure might be the result of a greater history of repeatedly overeating in the presence of food cues in these individuals. The authors suggested that over time, this pairing of overeating with the sight and smell of food, enables food cues to predict greater food intake in these children

Despite Jansen *et al*'s (2003) study, there has been little attempt to explore sensitivity to food cues in overweight, and non-overweight, *adults* using a modern cue reactivity paradigm. Yet, this issue is particularly important given the recent increases in the prevalence of obesity in both the UK (Health Survey for England, 2004), and in the US (Flegal, *et al*, 2002). For this reason, the primary aim of Experiment 5 was to explore the extent to which being overweight is associated with greater food-cue reactivity among adults.

One previously unconsidered possibility is the extent to which overweight individuals' greater sensitivity to food cues is manifest as a greater appetite for the cued food, or as a greater motivation to eat any food. For example, does brief exposure to the sight and smell of pizza simply stimulate greater appetite for this food in overweight, relative to non-overweight, individuals, or does it generate a greater appetite for any food. This issue is important because it has consequences for how we might conceptualise the effects of food-cue exposure on maintaining overeating in overweight individuals, and consequently how interventions might be designed to reduce cued overeating. Thus, given the importance of this issue, the present experiment compared the consequences of exposure to the sight and smell of pizza for appetite for this food, and for appetite for various other foods. Given the success of the methodology employed in Experiment 4 to assess desired portion-size selections of various foods (chips, garlic bread, peanuts, chocolate, and chocolate cake) in a non-cued context, this approach was also adopted in the present experiment.

A secondary issue considered in this experiment was the extent to which food-cue reactivity is also associated with everyday portion-size selection, and separate

measures of dietary restraint and disinhibition. In Experiment 4, there was little evidence of a statistically significant association between changes in desired portion size and everyday portion-size selections. One possibility considered in the previous part of this chapter was that the motivational state (three hours food deprived or satiated) in which participants find themselves in when recalling everyday portion size selection *might* influence recall of their everyday portion-size selection, and thereby affect observed associations between this measure and food-cue reactivity. Given that in Experiment 4, everyday portion-size selection was measured prior to the buffet lunch (i.e., when participants were three hours food deprived), in the present experiment participants were asked to recall their everyday portion size after consuming items from the buffet lunch

6.3 Method

6.3.1 Overview and procedure

Given that the methodology used in Experiment 4 appeared to provide an adequate approach to testing food-cue reactivity, an almost identical procedure was used in the present experiment. The only methodological difference in this experiment was that participants were asked to recall their everyday portion size of the selected foods after, rather than before, the buffet lunch. This was because it was suggested in Experiment 4 that the motivational state in which participants find themselves in when recalling everyday portion size selection *might* influence this recall, and thereby affect observed associations between this measure and food-cue reactivity. All other elements of the procedure were identical to the procedure used in Experiment 4 (see Chapter 5)

6.3.2 Participants

One hundred and twenty participants were recruited via email from the population of female undergraduate students at Loughborough University (UK) (mean age = 20.95, $SD = 2.52$) (mean BMI = 22.89, $SD = 2.55$). The reason for recruiting a larger cohort of participants in this experiment than in the previous experiments (3 and 4) was motivated by two factors. Firstly, Field (2005) suggests that the required sample size for regression analysis with the number of predictors and control variables used in this experiment is at least 100, achieving 80 percent power. Secondly, in this experiment, participants were not recruited on the basis of whether they were normal weight or overweight. Rather, volunteers were recruited and then divided into an overweight, and normal weight, group. Thus, to obtain a reasonable number of overweight participants, and based on Field's (2005) instruction on sample sizes, it was decided that a sample size of 120 participants would be recruited. All participants gave written consent to participate in the study and were informed that they could withdraw at any time during the experiment. All participants were paid seven pounds (Sterling) for their participation.

6.3.3 Measures

1. Cue reactivity and dietary behaviour

Measures of cue reactivity, and dietary behaviours (dietary restraint, disinhibition, average everyday portion size) were identical to those used in Experiment 4 (see Chapter 5).

2 BMI

BMI was calculated in this experiment as $\text{weight(kg)} / [\text{height (cm)}^2]$. Participant's height was assessed using a stadiometer (Bodycare, Warwickshire, UK). Weight was measured using a set of weighing scales (Soehnle, Germany).

6.3.4 Data Analysis

The data analysis for this experiment was almost identical to that used in Experiment 4 (see Chapter 5). However, in this experiment there was an additional independent variable, namely BMI. To explore associations between BMI and the measures of cue reactivity, BMI scores were used to dichotomise individuals into a normal weight, ($\text{BMI} \leq 24.9$), and an overweight ($\text{BMI} > 24.9$), group. This resulted in 26 participants being classified as overweight ($\text{BMI} > 24.9$), and the remaining 94 as non-overweight ($\text{BMI} \leq 24.9$). Changes in measures of cue reactivity from pre- to post-cue exposure were assessed as outcome measures (subjective appetite and portion-size selection) and were compared across the two groups using separate regression analyses for each of these outcome variables. Again, this analysis allowed the corresponding pre-exposure measure, and liking for that food, to be controlled for by entering these measures as covariates into the regression model. The preliminary analyses conducted for this experiment were identical to those described in Experiment 4 (Chapter 5). However, when exploring the participants' characteristics, here, between-subject t-tests were also used to determine the extent to which these dietary behaviours were expressed to a greater extent in overweight, relative to non-overweight, individuals.

6.4 Results

6.4.1 Participant characteristics

Table 6.1 Means and standard deviations for participant characteristics

	<i>n</i>	Mean	SD
<i>Characteristic</i>			
BMI	120	22.89	2.55
TFEQ-disinhibition score	120	8.15	3.26
DEBQ-restraint score	120	2.93	0.84
Everyday portion size	120	3.68	0.81

Means and SD's for each of the participant characteristics are summarised in Table 6.1. It was desirable to determine the extent to which the dietary measures (dietary restraint, disinhibition, and everyday portion size) were associated with each other. Thus, a series of Pearson's correlation coefficients were calculated. The findings suggested that the individuals who obtained higher scores on the disinhibition scale selected larger everyday-portion sizes ($r = 0.22$, $p = 0.015$) and obtained higher scores on the DEBQ-restraint scale ($r = 0.34$, $p < 0.001$). Individuals with higher restraint scores were also more likely to report selecting smaller everyday portion sizes ($r = -0.21$, $p = 0.022$).

When exploring the extent to which these dietary behaviours were expressed to a greater extent in overweight, relative to non-overweight, individuals, the results of between-subject t-tests suggested that overweight individuals obtained significantly higher disinhibition scores ($t = 2.71$, $df = 118$, $p = 0.008$), reported consuming larger everyday portion sizes ($t = 2.49$, $df = 118$, $p = 0.014$), but did not differ to non-overweight individuals in their reported levels of dietary restraint ($t = 0.33$, $df = 118$, $p = 0.745$).

6.4.2 Baseline measures

It was desirable to establish that there were no significant differences in hunger or fullness, subjective appetite for the test foods, or portion-size selections across the three dietary measures (everyday portion-size selection, dietary restraint, and disinhibition) and BMI immediately prior to cue exposure. Regression analyses were used to assess these associations. In these analyses liking for the test foods were controlled for in the models for specific foods by entering this variable as a covariate into the regression model. These analyses suggested that neither subjective appetite, nor desired portion sizes, for any of the test foods differed across the predictor variables prior to cue exposure (all $p > 0.05$).

6.4.3 Descriptive statistics for measures of cue reactivity

Initially, it was desirable to explore the descriptive statistics for the measures of cue reactivity before and after cue exposure. Therefore, the means and standard deviations for each of the changes in subjective appetite and portion-size selections for the cued, and non-cued, foods are summarised in Table 6.2. The results of within-subject t-tests used to compare the pre- and post-exposure measures are also presented alongside these descriptive statistics. These analyses suggest that cue exposure significantly increased hunger, and significantly reduced fullness (Table 6.2). It also suggests that it increased desire-to-eat, and craving, for pizza, and chocolate, and increased craving for chips and garlic bread (Table 6.2). Finally, these analyses suggest that pizza-cue exposure significantly decreased portion-size selection of peanuts and chocolate cake (Table 6.2).

Table 6.2 Within-subject *t*-tests, means, and standard deviations, for pre-exposure, and post-exposure, subjective appetite and portion -size selections

	<i>n</i>	Pre-exposure		Post-exposure		<i>t</i> -value and significance	
		Mean	SD	Mean	SD	<i>t</i>	<i>p</i>
Hunger	120	15.13	16.952	20.58	18.423	4.50	<0.001*
Fullness	120	72.91	22.11	68.20	23.15	-3.21	0.002*
<i>Desire-to-eat</i>							
Pizza	120	20.55	22.33	30.70	27.22	5.58	<0.001*
Chocolate	120	33.57	28.70	28.50	26.66	-3.21	0.002*
Peanuts	120	11.32	14.99	10.01	14.80	-1.24	0.218
Chips	120	15.73	18.99	14.57	16.69	-1.41	0.256
Garlic bread	120	14.56	18.63	15.21	18.27	0.62	0.534
Chocolate cake	120	25.58	25.29	23.80	23.82	-1.51	0.133
<i>Craving</i>							
Pizza	120	17.33	21.40	26.97	27.15	5.69	<0.001*
Chocolate	120	28.52	27.70	25.99	26.50	-2.24	0.027*
Peanuts	120	8.97	13.39	9.50	14.44	0.63	0.529
Chips	120	11.78	19.91	14.60	18.27	3.05	0.003*
Garlic bread	120	11.21	15.67	13.85	17.37	2.13	0.035*
Chocolate cake	120	24.29	26.18	22.11	24.42	-1.79	0.076
<i>Desired portion size</i>							
Pizza (mm ²)	120	6450.80	9194.13	6301.14	5998.84	-0.21	0.834
Chocolate (pieces)	120	4.56	0.42	4.18	0.43	-1.31	0.193
Peanuts (g)	120	27.50	35.40	20.34	30.83	3.64	<0.001*
Chips (g)	120	23.19	21.81	20.90	25.44	-1.63	0.106
Garlic bread (mm ²)	120	3944.75	4106.00	4004.75	4055.49	0.27	0.791
Chocolate cake (mm ²)	120	1947.20	1651.30	1658.34	1729.46	3.31	0.001*

* denotes $p < 0.05$

6.4.4 Effects of food models on subjective appetite

Again, to substantiate the claim that the food models used in this experiment provided a non-cued measure of participants' desired portion sizes, the effect of these models on appetite was assessed by comparing ratings taken from before, to after, initial exposure to these models (i.e., when participants were indicating their pre-exposure desired portion sizes). These analyses suggested that using the food models to indicate pre-exposure portion-size selections significantly increased feelings of hunger ($t = 3.55$, $df = 119$, $p = 0.001$), and significantly reduced reported levels of fullness ($t = -2.44$, $df = 119$, $p = 0.016$). It also served to significantly increase craving, for chocolate ($t = 3.66$, $df = 119$, $p < 0.001$), peanuts ($t = 2.46$, $df = 119$, $p = 0.015$), and for chips ($t = 2.00$, $df = 119$, $p = 0.048$). However, visual inspection of the mean values for these changes suggests that they were modest at between 1mm and 4mm (see Table 6.3) on the 100mm VAS. All other measures of subjective appetite were not found to increase significantly (all $p < 0.05$) after pre-exposure portion-size selections. This suggests that the food models had a minimal, if any, effect on appetite. Therefore, they can be regarded as providing a relatively non-cued measure of portion-size selection.

Table 6.3 Means and standard deviations for hunger, fullness, craving for chocolate, craving for chips, and craving for peanuts, before and after pre-exposure portion size selections using the food models

	<i>n</i>	Before portion-size selection		After portion-size selection	
		Mean	SD	Mean	SD
Hunger	120	11.33	11.706	15.13	1.547
Fullness	120	76.74	17.99	72.91	22.114
Craving for chocolate	120	23.53	24.69	28.52	27.697
Craving for peanuts	120	7.18	10.704	8.97	13.39
Craving for chips	120	10.01	14.53	11.78	16.91

6.4.5 Cue reactivity and being overweight

Overweight individuals were not found to experience a greater change in hunger or fullness after cue exposure, or a greater change in subjective appetite (desire to eat and craving) for pizza (Table 6.4). However, being overweight was associated with a greater change in desired portion size of pizza (Table 6.4). Using the parameter estimates from the regression model for change in desired pizza size, this change was predicted in Kcalories for an overweight, and non-overweight, individual with an average liking for pizza (average liking for pizza = 70.83mm) and average pre-exposure desired pizza-size (6450.80mm² [174.17 kcalories]). These predictions are displayed in Figure 6.1. Visual inspection of this figure suggests that after pizza-cue exposure, overweight individuals increased their desired pizza size by 46.06 kcals. By contrast, the desired portion size of pizza selected by non-overweight individuals decreased by 17.22 kcals. To give some indication of how these changes affected the *total* amount that overweight and non-overweight individuals might consume after cue exposure, pre-exposure portion size was predicted¹¹ thus enabling the total number of calories that would be consumed by these individuals to be calculated through addition of the predicted change (Table 6.5).

It is also important to note that overweight, and non-overweight, individuals did not differ in their change in subjective appetite (craving and desire to eat), or portion-size selection, for any of the non-cued foods (Table 6.4). This is interesting because, together with the findings reported for the cued food, it suggests that pizza-cue exposure was unable to stimulate subjective appetite for both the cued, and non-cued, foods, but was able to elicit an exclusive increase in desired pizza size

¹¹ To predict pre-exposure portion size of pizza, this measure was modelled as an outcome variable in a regression analysis

Table 6.4 Adjusted¹ parameter estimates from linear regression models for associations between changes in the measures of food-cue reactivity and BMI, and everyday portion-size selection

		BMI > 24.9 (Reference BMI ≤ 24.9)			Everyday portion size		
	<i>n</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>
<i>Changes in measures of</i>							
<i>cue reactivity</i>							
Hunger	120	3.62	2.97	0.224	-0.76	1.49	0.612
Fullness	120	-5.18	3.61	0.154	-0.38	1.81	0.833
<i>Desire-to-eat</i>							
Pizza	120	6.80	4.36	0.122	2.18	2.22	0.328
Chocolate	120	-6.83	3.63	0.063	-2.66	1.82	0.148
Peanuts	120	-3.85	2.08	0.066	-2.45	1.02	0.017*
Chips	120	-3.64	1.91	0.059	-1.84	0.97	0.061
Garlic bread	120	3.31	2.26	0.146	0.33	1.16	0.774
Chocolate cake	120	0.85	2.90	0.769	0.39	1.45	0.787
<i>Craving</i>							
Pizza	120	5.74	3.99	0.153	1.79	2.03	0.378
Chocolate	120	-0.15	2.79	0.959	-1.61	1.40	0.253
Peanuts	120	-2.53	1.83	0.169	-1.95	0.89	0.029*
Chips	120	3.22	2.37	0.177	0.12	1.22	0.925
Garlic bread	120	-2.46	2.87	0.393	-0.02	1.46	0.983
Chocolate cake	120	-2.76	2.94	0.350	-1.26	1.47	0.392
<i>Desired portion size</i>							
Pizza (mm ²)	120	2343.13	1075.78	0.031*	1161.65	547.47	0.036*
Chocolate (pieces)	120	-0.527	0.681	0.441	-0.91	0.34	0.008*
Peanuts (g)	120	3.91	4.16	0.350	-0.48	2.09	0.818
Chips (g)	120	-207.75	528.02	0.695	-0.97	1.71	0.574
Garlic bread (mm ²)	120	-98.39	539.64	0.856	269.48	271.54	0.323
Chocolate cake (mm ²)	120	-66.03	202.92	0.745	-68.09	108.33	0.531

* denotes $p < 0.05$

¹ Adjusted for the relevant pre-exposure rating for all outcome measures, and adjusted for liking for the cued/non-cued food for food-specific outcome measures (e.g., change in craving for pizza, desired portion size of pizza)

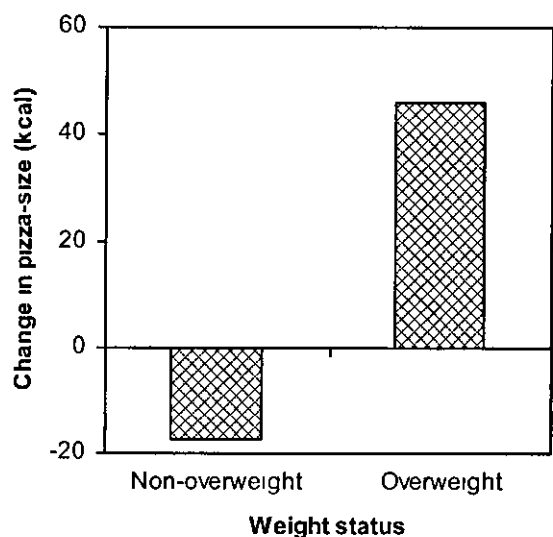


Figure 6 1 Predicted change in pizza-size in Kcalories (kcal) for overweight and non-overweight individuals after cue exposure estimated using the parameter estimates from the linear regression model ($B = 2343.13$)¹²

Table 6 5 Predicted values from the linear regression model for overweight, and normal weight, individuals for pre-exposure portion-size selection, and the total amounts these individuals would be expected to consume¹

	Pre-exposure pizza size (kcal)	Post-exposure pizza size (kcal)
Non-overweight	166.23	149.01
Overweight	203.59	249.63

¹ Holding liking for pizza, and pre-exposure pizza size, at their mean values for the sample (70.83mm, 6450.80mm² [174.17 kcalories], respectively)

¹² In this model liking for pizza and pre-exposure pizza size were held at their average values in the sample (average liking = 70.83mm, average pre-exposure pizza size = 6450.80mm² [174.17 kcalories]), and their respective parameter estimates ($B = 72.58$, $B = -0.68$, respectively) were used to predict the change in desired pizza size in Kcalories

6.4.6 Cue reactivity and everyday portion size

The findings suggest that average everyday portion size was not associated with changes in generalised measures of subjective appetite (hunger and fullness) or subjective appetite for pizza (craving and desire to eat) (Table 6.4). However, average everyday-portion size was significantly associated with change in desired portion size of pizza (Table 6.4), such that those participants who reported consuming larger everyday portion sizes on average, selected larger pizza-sizes after cue exposure. Again, using the parameter estimates from the regression model, the change in portion-size selection (represented in Kcalories) for individuals who reported consuming small (2 82), medium (3 71), and large (4.52), everyday portion sizes (calculated as the average value in each tertile of the data) were predicted after holding liking for pizza and pre-exposure portion-size selection at their mean values for the sample (70.83, and 174.17, respectively). These predictions are shown in Figure 6.2. To give some indication of how these changes affected the *total* amount that these individuals might consume, pre-exposure portion size selected by these individuals was again predicted¹³ thus enabling the total number of calories that would be consumed by these individuals to be calculated. These are summarised in Table 6 6.

¹³ To predict pre-exposure portion size of pizza, this measure was modelled as an outcome variable in a regression analysis

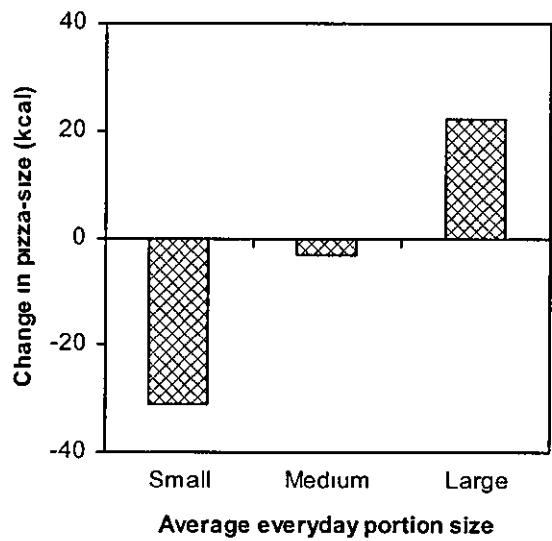


Figure 6 2 Predicted change in pizza size in Kcalories (kcal) for individuals with small (2 82), medium (3 71) and large (4 52) average everyday portion size (calculated as the average score in each tertile of the data) estimated using the parameter estimates from a linear regression model for change in pizza size ($B = 1161.65$)¹⁴

Table 6 6 Predicted values from the linear regression model for pre-exposure pizza size, and the total amounts individuals would be expected to consume in Kcalories for small, medium, and large, portion sizes (calculated as the average value in each tertile of the data)¹

	Pre-exposure pizza size (kcal)	Post-exposure pizza size (kcal)
<i>Everyday portion size</i>		
Small	141 40	110 28
Medium	175 09	171 89
Large	205 75	227 95

¹ Holding liking for pizza, and pre-exposure pizza size, at their mean values for the sample (70 83mm, 6450 80mm² [174 17 kcalories], respectively)

¹⁴ In this model pre-exposure pizza size and liking for pizza are held at their mean values in the sample (6450 80mm² [174 17 kcalories], and 70 83mm respectively) and their respective parameter estimates ($B = -0.70$, $B = 64.52$, respectively) were used to predict change in desired pizza size in Kcalories

With regards to the non-cued foods, changes in subjective appetite (craving and desire-to-eat) for chips, garlic bread, chocolate, and chocolate cake, did not differ significantly across average everyday portion size (Table 6.4). However, the consumption of larger everyday portion sizes was associated with a smaller change in desire-to-eat peanuts, and a smaller change in craving for this food (Table 6.4). Taken together therefore, these findings suggest that individuals who reported consuming larger everyday portion sizes did not experience greater subjective appetite for the cued, or non-cued, foods. Furthermore, desired portion-size selections of chips, garlic bread, peanuts, and chocolate cake did not differ significantly across average everyday-portion size (Table 6.4). However, the consumption of larger everyday portion sizes was associated with a decrease in desired portion size of chocolate.

6.4.7 Does being overweight act as a proxy measure of everyday portion size?

Notably, both being overweight and everyday portion-size selections are associated with change in desired portion size after cue exposure, and were found to be related to each other (see above). Given this, one possibility is that being overweight is associated with a greater change in desired portion size simply because overweight individuals have a tendency to select larger everyday portion sizes. To address this issue, post hoc, everyday portion-size selection was controlled for in the regression model assessing associations between change in desired portion size of pizza and being overweight by entering it as a covariate. If being overweight is associated with change in desired portion size independently of everyday portion size, then this variable should continue to be a significant predictor of this outcome variable. However, in this analysis, being overweight was no longer significantly associated with this change ($B = 1917.82$, $SE = 1097.08$, $p = 0.083$). This suggests that after the variation in change in desired portion size explained by everyday portion size selection is accounted for, being overweight fails to significantly predict this measure of cue reactivity.

6.4.8 Relationships between cue reactivity and dietary behaviour

Dietary-restraint scores were not associated with change in subjective appetite (hunger, fullness, craving, and desire-to-eat, the cued, and non-cued, foods), nor were they associated with change in portion-size selection of pizza, or of the non-cued foods (Table 6.7). This suggests that cue exposure did not have a differential effect for restrained, and unrestrained, eaters.

For individuals with high disinhibition scores, there was little evidence to suggest that they experienced a greater change in hunger (Table 6.7) than those who obtained lower scores on this scale, and in fact these individuals were found to experience a smaller decrease in fullness (Table 6.7). There was also little evidence of statistically significant associations between change in reactivity measures (subjective appetite and portion size selection) for the non-cued foods and disinhibition scores (Table 6.7), suggesting that changes in motivation to eat the non-cued foods did not differ across disinhibition scores. By contrast, higher disinhibition scores were associated with a greater increase in desire-to-eat pizza, a greater change in craving for this food, and the selection of larger desired portions of it (Table 6.7). However, these associations were no longer statistically significant after controlling for restraint status (all $p > 0.05$). This suggests that neither dietary restraint scores nor disinhibition scores were independently associated with changes in subjective appetite or desired pizza size, and that the variance in these variables was in fact explained by the shared contribution of dietary-restraint status and disinhibition scores.

Table 6.7 Adjusted¹ parameter estimates from linear regression models of associations between the two measures of dietary behaviour (TFEQ-disinhibition score, and DEBQ-restraint scores) and changes in measures of cue reactivity

		TFEQ-disinhibition scores			DEBQ-restraint scores		
	<i>n</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>
Changes							
Hunger	120	1.40	1.44	0.333	0.65	0.37	0.085
Fullness	120	-0.50	1.75	0.778	-0.92	0.46	0.048*
<i>Desire-to-eat</i>							
Pizza	120	1.76	2.14	0.413	1.15	0.54	0.036*
Chocolate	120	-0.77	1.80	0.670	-0.32	0.46	0.484
Peanuts	120	1.59	1.01	0.117	0.38	0.26	0.147
Chips	120	-0.63	0.94	0.503	0.07	0.25	0.781
Garlic bread	120	0.36	1.11	0.747	0.39	0.29	0.181
Chocolate cake	120	0.58	1.40	0.682	0.21	0.36	0.570
<i>Craving</i>							
Pizza	120	3.52	1.94	0.072	1.07	0.50	0.034*
Chocolate	120	1.32	1.37	0.338	0.06	0.35	0.856
Peanuts	120	1.50	0.88	0.092	0.34	0.23	0.139
Chips	120	0.85	1.16	0.463	0.46	0.30	0.128
Garlic bread	120	2.09	1.38	0.133	0.38	0.37	0.303
Chocolate cake	120	2.20	1.42	0.124	-0.46	0.36	0.208
<i>Desired portion size</i>							
Pizza (mm ²)	120	284.86	533.70	0.595	271.95	134.99	0.046*
Chocolate (pieces)	120	0.64	0.34	0.064	-0.12	0.09	0.172
Peanuts (g)	120	-1.79	2.03	0.378	-0.69	0.52	0.188
Chips (g)	120	1.69	1.65	0.307	-0.59	0.43	0.171
Garlic bread (mm ²)	120	178.47	261.02	0.496	58.27	67.65	0.391
Chocolate cake (mm ²)	120	99.72	105.14	0.345	-32.42	26.53	0.224

* denotes $p < 0.05$

¹ Adjusted for the relevant pre-exposure rating for all outcome measures, and adjusted for liking for the cued/non-cued food for food-specific outcome measures (e.g., change in craving for pizza, desired portion size of pizza)

6.4.9 Association between change in desired portion size and being overweight after controlling for disinhibition scores

Notably, overweight individuals were found to have higher disinhibition scores than non-overweight individuals, and greater dietary disinhibition was associated with a larger change in desired portion size of pizza after cue exposure. Given this, post-hoc, it was decided to assess the associations between being overweight and change in desired portion size after controlling for disinhibition scores. To do this, these scores were entered as a covariate into the regression model assessing the association between change in desired portion size and being overweight. This analysis suggests that after controlling for disinhibition scores, being overweight was not significantly associated with the change in desired portion size of pizza after exposure to this food ($B = 1926.27$, $SE = 1103.05$, $p = 0.083$).

6.4.10 Awareness questionnaire

Observation of the responses to the awareness questionnaire suggested that only a small percentage of participants indicated that they had some awareness of the aims of this experiment (Table 6.8). However, when prompted with particular questions about specific elements of the experiment, some participants (25.8%) did provide responses which suggested that they were aware of the experiment's interest in changes in subjective appetite after cue exposure (Table 6.8, question 2). To determine the extent to which this awareness affected the changes in subjective appetite, a series of regression analyses were conducted to explore associations between these changes and awareness of this aim. In these analyses, pre-exposure rating was controlled for by entering it as a covariate into the regression model, and where appropriate liking for the food was also controlled for. These analyses provided little evidence to suggest that awareness of the interest in the effect of cue exposure on subjective appetite affected the changes in these measures (all associations $p > 0.05$). In addition to this analysis, it was also desirable to determine the extent to which this awareness differed across the predictor variables (being overweight, everyday portion-size selection, dietary restraint, and dietary

disinhibition) Thus, a series of between-subject t-tests were used to explore dietary restraint scores, disinhibition scores, and average everyday portion size selections of those individuals who were aware of the aims of the experiment and those who were unaware, and a chi-squared test was used to compare awareness in overweight individuals and non-overweight individuals. These analyses provided little evidence to suggest that this awareness differed across the predictor variables (all $p > 0.05$).

Although the responses to the awareness questionnaire suggest that only a small number of participants were aware of the interest in the effect of cue exposure on portion-size selection, when participants were explicitly told that they were expected to select larger portion sizes in this experiment at the second time point (i.e., after cue exposure), over half the participants guessed that portion size of pizza was expected to increase. For this reason, again, it was desirable to determine the extent to which this awareness affected change in pizza portion size, and the extent to which it differed across the predictor variables (being overweight, everyday portion-size selection, dietary restraint, and dietary disinhibition) After controlling for liking for pizza and pre-exposure portion-size selection of this food in regression analyses, there was little evidence to suggest that this awareness predicted the change in pizza size observed after cue exposure (all $p > 0.05$). Furthermore, between-subject t-tests suggested that those individuals who were aware of this aim did not differ significantly in dietary restraint, average everyday portion size, or in their disinhibition scores (all $p > 0.05$) Likewise, a chi-squared test suggested that awareness did not differ significantly between overweight, and non-overweight, individuals ($p > 0.05$)

Table 6.8 Summary of responses to the awareness questionnaire All total are given in percentages

Question	Response	
	Aware (%)	Not aware (%)
1 What do you think was the purpose of this experiment?	15.8	84.2
2 I asked you to rate your mood and appetite twice during the experiment. Do you know why?	25.8	74.2
3 In this experiment I asked you to indicate the amounts of various foods that you would like to eat at that time. Do you know why?	8.33	91.67
4 I did expect you to want to eat greater amounts of the food than you might normally do at one time point. Which time point was this? (first or second)	61.6	38.4
5. I expected you to want to eat greater amounts of food than you might normally do at the second time point. Which food (s)?	68.3	31.7

6.4.11 Summary table of main results

To summarise the main results from this experiment a summary table (Table 6.9) is provided below. This summarises where statistically significant associations were observed between the predictor variables and the outcome measures. This suggests that dietary-restraint status was not significantly associated with any of the measures of food-cue reactivity. However, importantly, it does highlight significant associations between measures of motivation to eat the *cued* food and everyday portion-size selection, being overweight, and dietary disinhibition.

Table 6 9 Summary table of the significant associations between the predictor variables and the outcome variables for this experiment

	Predictor variables				
	Restraint	Disinhibition	Everyday portion size	Being overweight	
<i>Outcome measures</i>					
Change in hunger					
Change in fullness		✓			
Change in desire-to-eat pizza		✓ ₂			
Change in desire-to-eat chocolate					
Change in desire-to-eat garlic bread					
Change in desire-to-eat chips					
Change in desire-to-eat peanuts			✓*		
Change in desire-to-eat chocolate cake					
Change in craving for pizza		✓ ₂			
Change in craving for chocolate					
Change in craving for garlic bread					
Change in craving for chips					
Change in craving for peanuts			✓*		
Change in craving for chocolate cake					
Change in desired pizza portion		✓ ₂	✓	✓ ¹	
Change in desired chocolate portion			✓*		
Change in desired portion of chips					
Change in desired portion of peanuts					
Change in desired portion of garlic bread					
Change in desired portion of chocolate cake					

✓ Denotes where statistically significant interactions were observed

¹ This association was no longer statistically significant after controlling for everyday portion-size selection and dietary disinhibition

₂ This association was no longer statistically significant after controlling for dietary restraint scores

* Changes in these measures decreased as everyday-portion size increased

6.5 Discussion

This experiment primarily sought to explore the association between food-cue reactivity and being overweight. The results suggested that cue exposure did not have a greater effect on reported subjective appetite for pizza for overweight individuals relative to non-overweight individuals. However, it did have a differential effect on desired portion of pizza for these two groups of individuals. For overweight individuals, cue exposure served to increase desired pizza size. By contrast, for non-overweight individuals, it reduced desired portion size. Immediately, these findings suggest that cue exposure has a greater effect on desired portion for overweight individuals.

However, there are several other potential explanations for these findings. One possibility is that overweight individuals experienced a greater change in desired portion size in this experiment, because they had a greater awareness of the study's aims, and therefore were behaving in a way that they believed the researcher desired them to behave. Another possibility is that these individuals had a greater desire for the cued food prior to cue exposure, or that they were hungrier than the non-overweight individuals. Indeed, several neuroimaging studies have suggested that overweight individuals might experience weaker, or delayed, satiety signals (Gautier, Chen, Salbe, Bandy, Pratley, Heiman, *et al*, 2000. Gautier, Del Parigi, Chen, Salbe, Bandy, Pratley, *et al*, 2001). Thus, one possibility was that the overweight individuals in this experiment selected larger portion sizes of the cued food because they perceived themselves as less satiated after the buffet lunch than non-overweight individuals. However, against these possibilities, overweight individuals in this experiment were not found to have a greater awareness of the study's aims, have a greater appetite for the cued food at the outset, or report different levels of hunger or fullness relative to the non-overweight participants. Given this, it is most likely that differences in the change in desired portion in overweight, and non-overweight, individuals were the result of differences in sensitivity to foods cues between these two groups.

Notably, finding that overweight individuals are more food-cue reactive than non-overweight individuals is consistent with the results reported by Jansen *et al* (2003). These authors found that overweight children ingest larger amounts after pre-exposure to food, while non overweight children consume smaller amounts. Taken together, the importance of Jansen *et al* 's (2003) findings and those reported in the present experiment is that they provide support for the proposition that the eating behaviour of overweight individuals might be influenced to a greater extent by external environmental cues than the eating behaviour of non-overweight individuals. This possibility has been outlined previously in the externality hypothesis of obesity (Schachter, 1968, 1971). However, this hypothesis was replaced by the proposal that sensitivity to food cues is mediated by dietary-restraint status, rather than differences in BMI. Yet, the findings from the five experiments presented in this thesis suggest that restricting ones dietary intake does not cause greater susceptibility to food cues, and the present study suggests that overweight individuals are more sensitive to food cues than non-overweight individuals. Thus, perhaps Schachter's (1968, 1971) hypothesis was indeed correct and that being overweight is an important determinant of food-cue reactivity.

Given that the original proposals suggesting that being overweight might be an important determinant of sensitivity to food cues dates back to the 1970's, it is surprising that little consideration has been given to the *exact* consequences of cue exposure for food intake in these individuals. Specifically, there has been no attempt to determine the extent to which food-cue exposure is able to generate appetite for foods other than the one which has been cued in overweight individuals. Therefore, this experiment presents the first attempt to consider this issue by exploring changes in subjective appetite and desired portion size after cue exposure for the cued food, and for a series of non-cued foods. By doing this, the results of this experiment have provided little evidence to suggest that change in desired portion size, and subjective appetite, for the non-cued foods differed significantly in overweight, relative to non-overweight, individuals. However, given that change in desired portion size of pizza was elevated in overweight individuals relative to non-overweight individuals after cue exposure, this suggests that cue exposure is able to increase desired portion size of the *cued food* to a greater extent in overweight individuals, but is unable to similarly increase desired portion size of other foods.

It is important to consider why overweight individuals are specifically sensitive to food cues. There are several possible explanations for this. The first possible explanation is related to overweight individuals' tendency to consume larger amounts of food. In the present experiment, it was suggested that overweight individuals consume larger everyday portion sizes than non-overweight individuals. This might be important in explaining their greater food-cue reactivity because Jansen's (1998) theory of cue reactivity suggests that consuming larger amounts of food is the key determinant of greater food-cue reactivity. Specifically, Jansen (1998) proposes that heightened cue reactivity occurs because the consumption of larger portion sizes becomes associated with cues, such as the sight and smell of food. Consequently, on each occasion when these cues are encountered, they promote the selection of these larger portion sizes. Consistent with Jansen's (1998) proposal, the findings from the present experiment suggest that food-cue reactivity does share an association with everyday portion-size selection. Thus, given this, it is possible that overweight individuals, by dint of the fact that they typically consume larger portion sizes, might be *cued* to select larger amounts of a particular food after exposure to its sensory characteristics (i.e., the sight and smell). Notably, finding that overweight individuals *only* selected larger portion sizes of the cued food in this experiment relative to non-overweight individuals is in fact consistent with this possibility. This is because the sight and smell of pizza will *only* be associated with the selection of larger portion sizes of this food in overweight individuals. Thus, exposure to this cue will only be capable of stimulating the selection of larger portion sizes of this food.

The second potential explanation for the greater change in desired portion size of the cued food observed in overweight individuals relates to their tendency to obtain higher disinhibition scores. In this experiment, and in a series of previous studies (Bellisle *et al.*, 2004; Lindroos *et al.*, 1997), overweight individuals have been found to score higher on the TFEQ-disinhibition scale than non-overweight individuals. Thus, given that dietary disinhibition was found to be an important predictor of food-cue reactivity in this experiment, one possibility is that overweight individuals are more sensitive to food cues because they tend to be more disinhibited than non-overweight individuals. Notably, in the present experiment,

after controlling for disinhibition scores, being overweight was no longer significantly associated with change in desired portion size. Therefore, one possibility is that dietary disinhibition mediates the relationship between being overweight and change in desired portion size. Given that high scores on the disinhibition scale might reflect an inability to resist the temptation to eat offered by external triggers (social situations, emotional states, and external food cues) (see Section 4.5 in Chapter 4), this suggests that overweight individuals might be more susceptible to external food cues because they suffer to a greater extent from an inability to resist the temptation to eat offered by external triggers.

Unlike the explanations offered here for greater food-cue reactivity in overweight individuals, Jansen *et al* (2003) have presented an account based upon the idea that overweight individuals experience delayed satiety signals when consuming a food which has been cued, and for this reason consume larger amounts of this food. Central to Jansen *et al*'s (2003) explanation is the idea that a meal is terminated once the sensory characteristics of that meal (i.e., the taste, texture, sight, and smell) are no longer deemed desirable (Sensory-specific satiety [SSS], see Section 2.9, Chapter 2). Jansen *et al* (2003) suggest that for overweight individuals, during the intake of a cued food, this normal decline in the pleasantness of the sensory characteristics of the food is attenuated. Subsequently, this delays the development of satiety, and a greater amount of food is consumed. By contrast, Jansen *et al* (2003) suggest that for non-overweight individuals the decline in the pleasantness of the food's sensory characteristics (i.e., its sight and smell) begins during the exposure phase. Consequently, these individuals require smaller amounts of this food when it is subsequently offered for consumption before they reach SSS. Similar explanations could account for the differences in change in desired portion size observed after cue exposure in overweight, and non-overweight, individuals in this experiment. Indeed, the declining pleasantness of the sensory characteristics of the cued food in non-overweight individuals during cue exposure could account for the reduction observed in their desired portion size of the cued food. For non-overweight individuals, knowledge of the attenuated decline in the sensory characteristics of a cued food might have been gleaned from previous experiences of consuming cued foods. Thus, this knowledge might encourage these overweight individuals to select larger portion sizes of a cued food. However, it is important to

note that at present, these ideas are purely speculative and should be tested in future studies

One final reason why overweight individuals were found to be more sensitive to food cues than non-overweight individuals in this experiment might be related to differences in personality characteristics between these two groups of individuals. Perhaps relevant is that overweight individuals are found to be more impulsive than non-overweight individuals (Nederkorn *et al.*, 2006; Nederkorn *et al.*, in press), and to have a greater sensitivity to reward (Franken & Muris, 2005). Given that food-cue reactivity could conceivably be associated with a general inability to inhibit impulses generated by cues in the environment, and with a greater sensitivity to rewarding stimuli, such as a tasty food, one possibility is that these characteristics do in fact account for the greater food-cue reactivity observed in overweight individuals. However, to date, the potential role of these characteristics in food-cue reactivity has not been explored empirically. This is surprising given that such work might further develop our understanding of the fundamental processes which govern food-cue reactivity. For this reason, the associations between these characteristics and food-cue reactivity are considered in Experiment 6.

In addition to determining why overweight individuals might be more reactive to food cues than non-overweight individuals, it is equally important to consider the extent to which this greater reactivity might provide one explanation for why these individuals are overweight. It is logical to expect that those individuals who consume larger amounts each time they are cued with food, over time, will gain weight. Indeed, given that in the present study overweight individuals were found to desire larger amounts after cue exposure, it is possible that this greater sensitivity to food cues contributed to them initially becoming overweight. Notably, the results from this experiment also provide some scope to speculate as to how this might occur. Indeed, given that after controlling for everyday portion-size selections, the association between change in desired portion size and being overweight was no longer statistically significant, it is possible that everyday portion-size selection mediates the relationship between being overweight and the desire to consume greater amounts of a cued food. In light of this, one possibility is that greater sensitivity to food cues causes greater everyday food consumption which over time

results in individuals becoming overweight. However, in a cross sectional study such as that presented here, this represents only a speculation. To address this issue, studies are required which specifically assess the effect of greater sensitivity to food cues on weight gain. In the 1970's, Rodin, & Slochower (1976) addressed this issue by assessing weight gain during a summer camp, where food cues were naturally abundant, in teenage girls who were more or less sensitive to such cues. The authors found that teenage girls who were highly sensitive to food cues gained a larger amount of weight at summer camp than girls who were less sensitive to these cues. Thus, their study provided some initial evidence to suggest that greater sensitivity to food cues *might* promote weight gain. However, future studies should aim to replicate this finding using samples from different populations in different contexts.

Despite the fact that the present study can only speculate as to the effect of greater sensitivity to food cues on weight gain, given that overweight individuals were found to select larger portion sizes of a cued food, it is possible to conclude that greater sensitivity to food cues is likely to represent one factor which at least serves to maintain these individuals degree of overweight. This alone is important because at present, obesity is a major concern for public health. Therefore, it is important that interventions are designed to reduce levels of body weight in obese, and overweight, individuals. Thus, if food-cue reactivity constitutes one factor which might at least be responsible for individuals sustaining excess weight, one intervention might be to attempt to reduce food-cue reactivity in overweight individuals. Since food-cue reactivity is assumed to result from learned associations between the sensory characteristics of a food (visual and olfactory) and food ingestion (Wardle, 1990; Weingarten, 1985), to reduce reactivity it is feasible to suggest that these learned associations need to be 'extinguished.' Jansen (1998) suggested one technique for this called 'response prevention.' This involves presenting individuals with a food cue and preventing them from eating in the presence of this cue. A similar process has been successfully used to extinguish learned associations in bulimics (see Jansen, 1998 for details of this procedure) and alcoholics (Drummond & Glautier, 1994; Monti, Rohsenow, Rubonis, Niaura, Sirota, Colby, *et al* 1993). Thus, it is plausible that a similar technique might be

useful for extinguishing learned associations between the sensory characteristics of a food (visual and olfactory) and food ingestion.

In addition to exploring the role of being overweight in food-cue reactivity, and the implications of food-cue reactivity for everyday portion-size selections, a secondary issue considered in this experiment was the extent to which food-cue reactivity is also associated with separate measures of dietary restraint and disinhibition. The findings suggested that disinhibition scores were associated with a greater change in subjective appetite (desire to eat and craving) for pizza and a greater change in desired portion size of this food. By contrast, these scores were not associated with a greater change in subjective appetite, or desired portion-size selection, for any of the non-cued foods. Given that dietary disinhibition reflects a susceptibility to eat in the presence of external triggers, it is perhaps not surprising that disinhibited eaters experience a specific appetite for the cued food after cue exposure. This is because the pizza cue is likely to generate a *specific* trigger to eat pizza.

Consistent with results from the previous experiments presented in this thesis, in this experiment dietary-restraint status was not found to be associated with any of the measures of food-cue reactivity. Again this provides further support for the notion that restrained eaters have no greater sensitivity to food cues than unrestrained eaters. Notably, however, after controlling statistically for dietary restraint status when exploring associations between food-cue reactivity and disinhibition scores, these associations failed to reach statistical significance. This suggests that dietary restraint status was in some way accounting for the associations observed between dietary disinhibition and motivation to eat pizza. This finding is somewhat surprising given that dietary restraint has not been found to play any role in food-cue reactivity in any of the previous experiments presented throughout this thesis. The reason for this is also unclear. However, further ad-hoc inspection of the data suggested that a large proportion (75%) of individuals with high disinhibition scores also had high restraint scores, while less than half of the individuals (41%) with low disinhibition scores had high restraint scores. Therefore, one possibility is that this tendency for individuals with high disinhibition scores to have restraint scores resulted in associations between food-cue reactivity and

disinhibition scores failing to reach statistical significance after controlling for the effects of restraint on food-cue reactivity

6.6 Chapter Summary

The experiment presented in this chapter (Experiment 5) compared sensitivity to food cues in overweight, and non-overweight, individuals. Interestingly, the results suggested that overweight individuals experience the greatest change in desired portion size of the cued food. This finding is important because it highlights the possibility that greater reactivity to food cues can promote weight gain. A secondary aim of this experiment was to re-consider associations between food-cue reactivity, and i) everyday portion-size selection, ii) dietary disinhibition, iii) and being overweight. Consistent with previous experiments reported in this thesis, there was little evidence to suggest that dietary restraint status was associated with greater food-cue reactivity. However, the findings did suggest that both dietary disinhibition, and everyday portion-size selection might be associated with this dietary phenomenon. Specifically, individuals with high disinhibition scores and those who reported selecting the largest portion sizes experienced the greatest changes in desired portion size of the cued food.

CHAPTER 7

INDIVIDUAL DIFFERENCES IN FOOD-SPECIFIC REACTIVITY IN FOOD-DEPRIVED AND NON-DEPRIVED INDIVIDUALS

7.1 Chapter overview

This chapter discusses the final experiment presented in this thesis. The primary aim of this experiment was to explore the extent to which individual differences in personality characteristics, namely impulsivity and the BAS (Behavioural Activation System) trait, can predict variation in food-cue reactivity. The secondary aim was to explore the extent to which these, and other individual differences (dietary restraint, dietary disinhibition, and body weight) in food-cue reactivity, differ across two motivational states, i.e., when individuals were food-deprived and after they had eaten to satiety. The first section of the chapter provides the background to these aims, and is followed by further sections outlining the methodology employed, the results observed, and a discussion of the findings.

7.2 Introduction

In Experiment 5 it was found that overweight individuals select relatively larger portion sizes of a cued food than non-overweight individuals. One potential explanation for this might be that differences in overweight individuals' personality render them more susceptible to the effects of food cues. In particular, these individuals' tendency to be more impulsive (Nederkoorn *et al.*, 2006; Nederkoorn *et al.*, in press), and to have a greater sensitivity to reward (Franken & Muris, 2005), might account for their greater reactivity to food cues. Given this, the aim of the present experiment was to assess the potential role of characteristics such as impulsivity and sensitivity to reward in food-cue reactivity.

Different levels of sensitivity to reward are assumed to be mediated by the Behavioural Approach system (BAS). The BAS was described in Chapter 2. Essentially, it is a hypothetical brain structure that responds to stimuli in the environment which are rewarding, or which are associated with a reward by activating behaviour (see Chapter 2 for further details). This activation system might be important for food-cue reactivity given that cue reactivity is likely to arise because a food cue has gained the capacity to signal the receipt of a tasty reward. Therefore, it follows that those individuals who have a highly reactive BAS and thereby are more sensitive to cues signalling reward, might be more reactive to food cues (see Chapter 2 for further details). Given this, one aim of the present study was to explore evidence for an association between activity of the BAS and food-cue reactivity. To do this, the BAS trait was assessed using the Sensitivity to Reward scale (SR) from the Sensitivity to Reward and Sensitivity to Punishment Questionnaire (SRSPQ, Torrubia, Avila, Molto, & Caseras, 2001)

As suggested in Chapter 2, impulsivity is defined as an inclination to act in a rash, and unplanned, manner, towards environmental stimuli. Therefore, individual differences in this trait might also be associated with sensitivity to environmental stimuli associated with food ingestion. Put simply, impulsive individuals would be expected to execute a rash response to food cues, giving little consideration to the consequences of this action. By contrast, less impulsive individuals might consider the implications of consuming larger amounts of cued food, and as a consequence refrain from selecting these larger portion sizes. Given that this possibility has not previously been considered, the present study also sought to explore associations between food-cue reactivity and impulsivity. To do this, impulsivity was assessed using a self-report measure of impulsivity, namely the impulsivity scale from the Eysenck Personality Questionnaire (i.e., Eysenck & Eysenck, 1975), and by assessing inhibitory control. Since impulsivity reflects a deficit in inhibitory control, it was desirable to obtain a measure of this deficit. This was achieved by using the Stop-Start task (Logan, Schachar, & Tannock, 1997). This task was recently utilised by Nederkoorn, *et al* (2004) in a study of food-cue reactivity. However, rather than assessing the association between measures of food-cue reactivity and inhibitory control, the authors explored the extent to which food-cue exposure *promotes*

deficits in inhibitory control. Thus, the present experiment constitutes the first attempt to assess associations between food-cue reactivity and trait impulsivity and inhibitory control.

A secondary aim of this experiment was to compare individual differences in food-cue reactivity when individuals are food deprived and when they are non-food deprived. In the experiments presented thus far in this thesis individual differences in food-cue reactivity have been assessed in the absence of food deprivation. The initial decision to test individuals in this state was motivated by Weingarten's (1985) proposals regarding conditioned meal initiation. Weingarten (1985) suggested that if food-cue reactivity reflects a learned response it should be evident even when individuals are non-food deprived. However, as suggested in the opening chapters of this thesis when exploring individual differences in food-cue reactivity it might also be important to ascertain that the same individual differences exist when individuals are in fact modestly deprived of food. This is particularly important given that there is reason to suspect that some associations between the predictor variables used in this thesis and food-cue reactivity might be exclusive to a satiated state. Indeed, it is suspected that overweight, and non-overweight, individuals might only respond differently to food cues when they are satiated. When modestly deprived of food, these two groups of individuals might in fact behave in a similar way. Evidence for this possibility comes from the externality hypothesis devised by Schachter (1968, 1971). This hypothesis suggests that overweight individuals rely exclusively on external food cues to control their food intake. Thus, these individuals are likely to react consistently to an external food cue irrespective of their internal motivational state. By contrast, the hypothesis suggests that non-overweight individuals rely on internal physiological signals, and thus, would be expected to respond to a food cue only when they are hungry. Given this, it follows that reactivity to food cues might be similar in overweight, and non-overweight, individuals when they are deprived of food, but differ when these individuals are satiated. This is because when satiated non-overweight individuals are unlikely to react to food cues given that their internal physiological signals do not promote the intake of food. By contrast, for non-overweight individuals, even when satiated, external food cues will offer a tempting reward. In light of this, the present experiment also sought to explore individual differences in food-cue reactivity when

individuals were food-deprived, and in the absence of hunger. In addition to exploring how individual differences in BAS activity and impulsivity are associated with food-cue reactivity in these deprived, and non-deprived, states, it was also important to explore how differences in body weight, dietary restraint, and dietary disinhibition relate to food-cue reactivity in these states.

To summarise, the objective of this experiment was to explore associations between the measures of cue reactivity used in the preceding experiments (subjective appetite and portion-size selection) and i) dietary restraint, ii) disinhibition, iii) being overweight, iv) BAS activity, and v) impulsivity, when individuals were food-deprived and in the absence of food deprivation. Food deprivation was manipulated by asking participants to refrain from eating for four hours prior to initial pizza-cue exposure, and then by asking them to consume items from a buffet lunch until they felt comfortably full prior to a second identical pizza-cue exposure phase. This allowed associations between the measures of cue reactivity and the five predictor variables (dietary restraint, dietary disinhibition, body weight, BAS trait, and impulsivity) to be explored after four hours food deprivation and immediately after eating to satiety.

7.3 Method

7.3.1 Overview

This experiment comprised five phases; i) pizza-cue exposure before lunch, ii) buffet-style lunch, iii) pizza-cue exposure after lunch, iv) Stop Start task, and v) a questionnaire phase (TFEQ-disinhibition scale, DEBQ-restraint scale, Impulsivity scale, SR scale, and awareness questionnaire). Phases i) and iii) (the exposure phases) were identical to each other except that in phase (i) participants had been deprived of food for at least four hours, while in phase (iii) they were satiated after the buffet lunch. As in Experiments 4 and 5, in these exposure phases, participants were exposed to the sight and smell of pizza for three minutes. Immediately before and after this exposure they rated their subjective appetite for the cued (pizza), and

non-cued (chips and chocolate cake), foods and indicated their desired portion size of these foods. Again, portion sizes were assessed using food models identical to those used in Experiments 4 and 5. Measures of general subjective appetite (hunger and fullness) and measures of specific appetite (desire to eat and craving) were taken before and after each of the pre-exposure measures made using these models to ensure that these models were providing a non-cued assessment of portion-size selection.

7.3.2 Design

This experiment employed a within-subjects design. Changes in motivation to eat elicited by the food cue were observed in each participant after four-hour deprivation, and following lunch. The reason this approach was employed was because it increases the power of the design since cue reactivity is observed in each participant in both a food-deprived, and non-deprived, state.

7.3.3 Participants

One hundred and twenty participants were recruited from the population of female students at Loughborough University (mean age = 20.08, SD = 2.24). In the most part, the sample was self-selected. Participants who wished to take part volunteered for the study after receiving an email advertisement. However, in the final stages of recruitment, non-overweight participants were not recruited, and overweight participants were actively selected using the details provided on a pre-screening health questionnaire (see Appendix F). This was because fewer overweight participants initially volunteered for this experiment relative to the number of overweight volunteers recruited in Experiment 5. Therefore, to ensure that a similar number of overweight participants were recruited in this experiment these individuals were actively selected.

7.3.4 Measures

1. Cue reactivity

The measures of cue reactivity used in this experiment were identical to those used in the previous experiments. Full descriptions of these measures are presented in the preceding chapters. The only difference was that in this experiment measures of appetite (subjective appetite and desired portion size) were only assessed for two non-cued foods. These were chips and chocolate. The reason for this was to reduce the complexity of the design because there were two exposure phases. It was decided that this would not be detrimental to the study given that in previous studies there has been little differential effect of cue exposure on appetite for non-cued foods.

2 *Being overweight, dietary disinhibition, and dietary restraint*

These characteristics were assessed and defined in the same way as in the earlier experiments described in this thesis.

3 *Sensitivity to reward*

Activity of the BAS was assessed in this experiment using the SR scale from the SRSPQ (Torrubia, *et al*, 2001). This scale has good internal consistency, test-re-test reliability, and construct validity (see Torrubia *et al*, 2001). An alternative measure of the BAS are the BAS scales (BAS-fun seeking, and BAS-reward responsiveness) developed by Carver & White (1994). However these scales are less desirable than the SR scale of the SRSPQ scale because the items relate to the non-specific concept of reward. By contrast the items on the SR scale relate to *specific* rewards and appraisal, and therefore can be interpreted with less ambiguity.

The SR scale comprises 24 items which assess sensitivity to rewards such as money, sex, social power, and approval, and appraisal (e.g., Does the good prospect of obtaining money motivate you strongly to do some things?) (See Appendix G for the full list of the items included in this questionnaire.) Participants are requested to respond with either a 'yes' or 'no' to each item. 'Yes' responses score one point,

and 'no' responses score zero points. Points are totalled across the 24 items resulting in a single measure of sensitivity to reward out of a total score of 24.

4 Impulsivity

Self-report impulsivity was assessed using the Impulsivity scale from the EPQ (Eysenck & Eysenck, 1975). This scale comprises 19 items which assess a tendency to act on impulse without sufficient forethought (See Appendix H for the specific items included in this questionnaire.) Again, participants are requested to respond with either a 'yes' or 'no' to each item. For most items, 'yes' responses score one point, and 'no' responses score zero points. However, for some items this scoring is reversed. For example, the scoring of the item 'Before making your mind up, do you consider all the advantages and disadvantages?' would be scored backwards. By totalling the points scored across the nineteen items an impulsivity score can be derived.

Response inhibition was assessed in this experiment using the Stop Signal task (Logan, *et al.*, 1997). This task has been used extensively to assess deficits in inhibitory control in individuals with Attentional Deficit Hyperactive Disorder (ADHD) (e.g., Bekker, Overtoom, Kenemans, Kooij, De Noord, Buitlaar *et al.*, 2005; Schachar, Tannock, Marriot, & Logan, 1995). In this experiment, the task was copied from Logan *et al.* (1997) and was created using E-prime software. During this task participants were required primarily to respond to a choice reaction-time task ('go' task). The letter 'O' and 'X' were presented for 1000 milliseconds (ms) on the centre of a computer screen. Participants were asked to respond to the 'X' by pressing the 'x' key on a standard keyboard and to respond to an 'O' by pressing the 'o' key on the same keyboard. They were also told to press the keys as quickly as possible. On 25% of the 'go' trials, however, a 1000Hz tone would sound. Participants were told that when they heard this sound they should *not* respond to the 'go' task. This was defined as the 'stop' task. Initially, on trials where the 'stop' sound signalled, it occurred 250ms after the 'go' signal, i.e., 250ms after the letter appeared on the screen. If the participants failed to inhibit their response, the 'stop' signal was produced 50ms earlier, thereby making it easier for participants to inhibit their response when the next 'stop' signal occurred. In contrast, if the participant successfully inhibited their response, the delay of the stop signal was reduced by

50ms making it more difficult to inhibit the next 'stop' signal trial. The two variables measured in this task are reaction time (RT) and the stop delay. The stop-signal reaction time (SSRT) is calculated by subtracting the stop delay from the reaction time for these trials where the participant provided the correct response to the reaction-time choice task (i.e., by pressing 'o' or 'x' correctly in response to the letter observed on the screen). The task consists of one block containing 32 trials. There were an equal number of 'X's' and 'O's' across the trials. Participants were given an opportunity to familiarise themselves with the task before these trials began.

5 Awareness Questionnaire

Again, an awareness questionnaire was issued at the end of the experiment to ensure that participants were not aware of the aims of this experiment. This questionnaire asked 1) What do you think was the purpose of this experiment?, 2) I asked you to rate your mood and appetite during the experiment. Do you know why?, 3) I asked you to indicate the amounts of pizza, chocolate cake, and chips, that you would like to eat at various points during the experiment. Do you know why?, 4) I expected that you would want to eat greater amounts of these foods than you might normally do at certain times during the experiment, a) Which time(s) do you think this/these was/were?, b) Which food(s)?, and 5) Do you know why you were offered lunch in this experiment?

7.3.5 Procedure

As in other experiments presented in this thesis, before arriving to be tested the participants were told that the aim of the experiment was to explore the relationship between 'appetite and mood.' They were also told that they would have to rate their mood throughout the experiment, that they would be asked to offer an opinion on various foods, and that they would receive a buffet-style lunch.

Participants were tested between 11am and 3pm. All were instructed to refrain from eating for four hours prior to the onset of the experiment. To check compliance with this, participants were asked to record their intake prior to their test session. On

arrival at the laboratory, participants provided a set of appetite ratings which served as a baseline measure of subjective appetite prior to pre-exposure portion-size selections. Immediately after completing these ratings, participants were invited to make their pre-exposure portion size selections. Following this, a second set of appetite ratings was taken. This measure allowed exploration of the effects of making these portion-size selections on appetite, and also served as a pre-exposure measure of subjective appetite. Consistent with the cover story, these subjective measures of appetite also included a number of ratings relating to the participant's current mood. After this, the participants were then exposed to the sight and smell of cooked pizza for three minutes. The pizza was presented in a rectangle slice, and weighed 300g (810 kcal). It was placed on a table directly in front of the participant. During this exposure phase, participants were instructed to sit and wait until the experimenter returned. After exposure, the participants provided post-exposure portion-size selections and appetite ratings. They were then presented with a buffet-lunch and were asked to eat until they felt 'comfortably full.' After lunch, the same procedure as that described above was repeated to provide a measure of the effects of pizza-cue exposure on motivation to eat while individuals were non-food deprived. Following this, participants completed the Stop Signal task, the TFEQ-disinhibition scale, the DEBQ-restraint scale, the SR scale, the impulsivity questionnaire, the awareness questionnaire, and rated their liking for the cued (pizza), and non-cued (chips and chocolate cake), foods. Finally, a measure of height and weight was taken, and BMI was calculated.

7.3.6 Data Analysis

The aim of this experiment was to explore associations between the measures of cue reactivity and i) dietary restraint, ii) dietary disinhibition, iii) being overweight, iv) BAS activity, v) self-report impulsivity, and vi) response inhibition (assessed using scores on the Stop Signal task) in two different motivational states, i.e., when individuals were food deprived, and immediately after they had eaten to satiety. Measures of cue reactivity taken in this experiment included two measures of general subjective appetite (hunger and fullness), two measures of specific

subjective appetite (desire-to-eat and craving) for the cued (pizza), and non-cued (chips and chocolate cake), foods, and a measure of desired portion size of these foods. To assess cue reactivity, four sets of these measures were taken. One set was taken prior to cue exposure, in both the first (before lunch), and second exposure (after lunch), phases (pre-exposure sets), and one set was taken following cue exposure, in both the first, and second, exposure phases. Initially, descriptive statistics (means and SD's) for these outcome measures were assessed and within-subject t-tests were calculated to determine the extent to which they differed from before, to after, pizza-cue exposure. In addition to this, preliminary analyses also sought to ensure that the use of food models for the pre-exposure measures provided a non-cued measure of participants' desired portion sizes. To do this, within-subject t-tests were used to compare general subjective appetite (hunger and fullness) and subjective appetite (desire to eat and craving) for the cued, and non-cued, foods. If these food models were providing a non-cued measure, there should be little change in subjective appetite. Finally, as part of the preliminary analyses, descriptive statistics for participant characteristics (sensitivity to reward, impulsivity, BMI, dietary restraint, and dietary disinhibition) were produced. Following from this, a series of Pearson Correlation Coefficients were calculated to assess associations between the linear measures (i.e., sensitivity to reward, impulsivity, dietary restraint, and dietary disinhibition), and between-subject t-tests were used to assess the extent to which these linear characteristics differed across overweight, and non-overweight, participants.

After conducting these preliminary statistics, change scores for each of the cue reactivity outcome measures (general appetite, subjective appetite, and desired portion size) after cue exposure were derived from the difference between the measure of reactivity taken before, and after, pizza-cue exposure. These change scores were derived for the measures taken when participants were hungry and when they were satiated. Separate regression models were used to explore the associations between these change scores and each of the predictor variables (dietary restraint, dietary disinhibition, BMI, impulsivity, and the BAS trait). As in previous experiments, in each of these models, pre-exposure reactivity measures were controlled for by entering these measures as covariates into the regression model. In addition to this, where food-specific outcome measures were being

modelled, liking for the cued/non-cued food was also controlled for. Importantly, all predictor variables were entered into the regression model as continuous variables except BMI. As in Experiment 5 (Chapter 6), BMI scores were used to dichotomise individuals into a normal weight, ($BMI \leq 24.9$), and an overweight, ($BMI > 24.9$), group, and comparisons were made between these two groups. Twenty-six participants were classified as being overweight ($BMI > 24.9$), and the remaining 94 as non-overweight ($BMI \leq 24.9$). Again, as in previous experiments presented in this thesis it was important to determine the extent to which any associations between the outcome measures and disinhibition scores occurred irrespective of restraint status. Thus, where significant associations were reported for disinhibition, a second regression model was run which controlled statistically for restraint scores. Similar to this, since sensitivity to reward and impulsivity are likely to be related to each other, it was important to explore the extent to which these characteristics were independently associated with cue reactivity. For this reason, where significant associations were reported between either of these variables and one of the outcome measures, the regression model was re-run controlling for the other variable by entering it as a covariate into the regression model. Where outliers were observed in the data, the analysis is reported with these outliers in the data set and with them removed.

As in the previous experiments, statistically significant associations between an outcome variable and the predictor variables are depicted graphically by using the parameter estimates from the appropriate regression model to predict the change in the outcome measure for different values of the predictor variable after controlling for the effect of any confounding variable, such as pre-exposure measures of reactivity. Where the predictor variable was a continuous measure this variable is split into tertiles. An average measure of this variable was then calculated for each tertile of the data, yielding a low, medium, and high, score. After predicting the changes in the outcome measures, where changes were observed in portion-size selection, it was also desirable to gain some insight into the effect of this change on the *total* portion size likely to be consumed after cue exposure. To do this, initially, a regression model was constructed to model pre-exposure portion size controlling for liking for the food across the tertiles of the relevant predictor variable. The parameter estimates from this model were then used to predict pre-exposure size

across the three levels. By summing this pre-exposure portion-size prediction to the change in this measure observed after cue exposure, the total portion size which would be consumed after cue exposure was calculated.

7.4 Results

7.4.1 Outliers

One participant was removed from the data set as she had a BMI of 13, which indicated that she was severely undernourished. Another participant experienced a change in desired pizza size when hungry which was 5.57 standard deviations above the mean change in this measure. Inspection of the data suggested that this change equated to a change of 2376 Kcalories. This change in of itself exceeds the recommended daily Kcalorie intake for women, suggesting that this measure was likely to have been an error. Since it is possible that if this participant made an error in estimating their desired pizza size, they also made errors in other measurements provided throughout the experiment, this participant's data was also removed from the data set.

A further two participants appeared to be incorrectly completing the rating scales. This is because initially they rated their hunger as relatively high (83mm and 94mm) and their fullness as relatively low (1mm and 7mm), but then following the first pre-exposure portion-size selections using the food models, their hunger ratings decreased to a level which would indicate that they were not hungry (1mm, and 24mm) and their fullness increased to level which would suggest they were in fact satiated (99mm, and 72mm). However, after exposure to the pizza, their high levels of hunger (99mm and 96mm) and reduced levels of fullness (1mm, and 3mm) returned. One possibility is that in the second set of ratings these participants confused the hunger and fullness ratings. Since it is also possible that these participants made other errors throughout the experiment, the analysis was run with, and without, these participants included. Any differences in the findings which occur as a result of these participants being included in the analysis will be reported

in the following sections. Where the inclusion of their data did not alter the statistical significance of the findings, the results are presented with these data points excluded

7.4.2 Participant characteristics

Characteristics of the participants are summarised in Table 7.1. Mean values for the majority of these characteristics are similar to those observed in previous experiments. However, mean stop start signal scores were much greater than would be expected. This is because the mean score was approximately 100ms greater than that reported in previous studies (e.g., Nederkoorn *et al* , 2004).

Table 7.1 Mean and standard deviations for participant characteristics

	<i>n</i>	Mean	SD
<i>Characteristic</i>			
BMI	118	22.88	3.34
TFEQ-disinhibition score	118	8.42	3.02
DEBQ-restraint score	118	2.68	0.85
Sensitivity to reward score	118	11.37	3.95
Impulsivity score	118	7.60	4.34
Stop start signal task score [ms] (reaction time [ms])	118	265.34 (444.05)	201.63 (101.13)

Exploration of the association between each of the participant characteristics suggested that higher disinhibition scores were associated with higher EPQ-impulsivity scores ($r = 0.24$, $p = 0.008$), higher DEBQ-restraint scores ($r = 0.44$, $p < 0.001$), and higher sensitivity to reward scores ($r = 0.22$, $p = 0.019$). Furthermore, higher EPQ-impulsivity scores were associated with higher scores on the sensitivity to reward scale ($r = 0.39$, $p < 0.001$). Finally, overweight individuals had higher TFEQ-disinhibition scores ($t = 3.18$, $df = 114$, $p = 0.002$) and higher DEBQ-restraint scores ($t = 3.33$, $df = 114$, $p = 0.001$) than non-overweight individuals

While overweight individuals obtained scores of 3.18 and 10.12 respectively on the restraint and disinhibition scales, non-overweight individuals obtained scores of 2.56 and 8.04 respectively.

7.4.3 Baseline measures

Prior to the initial cue exposure phase, there was little evidence to suggest that hunger, fullness, or appetite (desire to eat and craving) for the cued, and non-cued, foods differed across the predictor variables (dietary restraint, disinhibition, body weight, impulsivity, BAS trait). However, after lunch, prior to the second cue exposure phase, desire-to-eat pizza ($r = 0.19$, $p = 0.039$) and craving for this food ($r = 0.26$, $p = 0.005$), were significantly greater in individuals with high impulsivity scores. However, since pre-exposure measures were controlled for statistically in the regression analyses exploring changes in the measures of cue reactivity and impulsivity, these differences should not have any impact on the observed results. All other associations between pre-exposure measures before lunch and the predictor variables were not statistically significant (all $p > 0.05$).

7.4.4 Lunch manipulation

To ensure that the lunch manipulation was effective and that individuals were relatively hungry prior to cue exposure before lunch, and relatively satiated prior to cue exposure after lunch, mean ratings of baseline hunger and fullness were assessed before and after lunch. These are displayed in Table 7.2. Within-subject t -tests suggested that hunger levels were significantly greater before lunch ($t = -25.66$, $df = 116$, $p < 0.001$) and levels of fullness were significantly greater after lunch ($t = 28.31$, $df = 116$, $p < 0.001$).

Table 7.2 Means and standard deviations for baseline hunger (mm) and fullness (mm) before, and after, lunch

	<i>n</i>	Before lunch		After lunch	
		Mean	SD	Mean	SD
Hunger	118	64.82	20.88	11.91	11.81
Fullness	118	13.96	16.97	73.04	16.78

7.4.5 Descriptive statistics for measures of cue reactivity

Within-subject *t*-tests exploring measures of motivation to eat obtained both before, and after, pizza-cue exposure are shown in Tables 7.3 (hungry state before lunch) and 7.4 (satiated state after lunch), respectively. The statistics in parenthesis (brackets) represent the findings after the removal of outliers associated with these variables. These outliers were between 4 and 7 standard deviations away from the mean. However, they had little impact on the statistical significance of the observed results.

Inspection of Table 7.3 suggests that before lunch, hunger was significantly increased after cue exposure, and that fullness was significantly reduced. It also suggests that subjective appetite (desire-to-eat, and craving) for pizza was significantly greater after cue exposure. By contrast, appetite for the non-cued foods (chips and cookies) was significantly reduced after pizza-cue exposure, suggesting that cueing with pizza did little to stimulate appetite for these foods. A similar pattern of results was also evident for portion-size selections before lunch. Only desired portion size of pizza increased significantly after cue exposure. The mean desired portion size of pizza prior to cue exposure comprised 825.74 kcal (*SD* = 531.98 kcal), whilst the mean desired portion size after cue exposure comprised 926.78 kcal (*SD* = 629.55).

After lunch, the findings revealed that hunger significantly increased from before to after cue exposure and fullness decreased significantly (Table 7.4). Appetite (desire to eat and craving) for pizza, and desired portion size of this food, again were also

significantly greater after cue exposure, whilst appetite (desire to eat and craving) and desired portion size for the non-cued foods did not differ significantly (Table 7 4). Prior to cue exposure, the mean desired portion size of pizza comprised 175.75 kcal ($SD = 224.87$ kcal). By contrast, after cue exposure it comprised 291.17 kcal ($SD = 338.08$ kcal)

Table 7 3 Within-subject t-tests, means, and standard deviations, for changes in hunger (mm) and fullness (mm) and changes in appetite ratings (desire to eat and craving) (mm) and portion-size selection, for the cued (pizza,) and non-cued, foods (chips, and chocolate cake) before lunch

	Pre-exposure			Post-exposure		<i>t value and significance</i>	
	<i>n</i>	Mean	SD	Mean	SD	<i>t</i>	<i>p</i>
<i>Changes</i>							
Hunger (mm)	118	66.87	23.48	72.21	23.02	3.44	0.001*
Fullness (mm)	118	16.87 (16.77)	17.51 (17.55)	13.61 (12.59)	16.41 (15.27)	-4.08 (-5.44)	<0.001* (<0.001)*
Desire-to-eat pizza (mm)	118	57.80	29.71	69.70	27.99	6.45	<0.001*
Desire-to-eat chips (mm)	118	49.88	29.42	44.35	28.21	-3.84	<0.001*
Desire-to-eat chocolate cake (mm)	118	52.97	29.64	46.51	29.08	-3.94	<0.001*
Craving for pizza (mm)	118	51.56	31.47	64.59	29.61	6.45	<0.001*
Craving for chips (mm)	118	44.74	30.01	39.03	28.69	-3.04	0.003*
Craving for chocolate cake (mm)	118	50.23	29.43	43.78	28.12	-3.82	<0.001*
Pizza size (mm ²)	118	30582.91	19073.60	34235.19	23316.81	3.03	0.003*
Portion of chips (g)	118	72.95	43.51	69.15	45.81	-1.42	0.158
Portion of chocolate cake (mm ²)	118	5552.72	4554.26	4360.68	4107.10	-5.54	<0.001*

* denotes $p < 0.05$

() Statistics once outliers are removed from the data set. The outlier was 5.61 standard deviations above the mean.

Table 7.4 Within-subject t-tests, means, and standard deviations, for changes in hunger (mm) and fullness (mm), and changes in appetite ratings (desire to eat, and craving) (mm) and portion-size selection, for the cued (pizza), and non-cued (chips, and chocolate cake), foods after lunch

		Pre-exposure		Post-exposure		<i>T-value and significance</i>	
	<i>n</i>	Mean	SD	Mean	SD	<i>t</i>	<i>p</i>
<i>Changes</i>							
Hunger (mm)	118	14.09	13.99	20.59	17.00	5.27	<0.001*
Fullness (mm)	118	72.35	19.59	68.27	21.38	-2.78	0.006*
		(72.13)	(19.53)	(68.82)	(20.61)	(-2.64)	(0.010)*
Desire-to-eat pizza (mm)	118	15.99	20.04	26.66	25.36	6.12	<0.001*
		(15.30)	(18.67)	(26.70)	(25.47)	(7.13)	(<0.001)*
Desire-to-eat chips (mm)	118	13.27	18.61	12.97	17.66	0.34	0.737
		(13.31)	(18.68)	(12.59)	(17.27)	(0.90)	(0.368)
Desire-to-eat chocolate cake (mm)	118	19.33	21.65	17.47	20.88	1.37	0.175
		(18.82)	(21.04)	(17.59)	(20.93)	(1.01)	(0.316)
Craving for pizza (mm)	118	14.76	20.67	24.43	26.56	5.35	<0.001*
		(14.04)	(19.26)	(24.49)	(26.67)	(6.33)	(<0.001)*
Craving for chips (mm)	118	11.23	17.06	11.53	16.23	0.48	0.632
Craving for chocolate cake (mm)	118	17.76	22.25	16.09	19.09	1.42	0.160
		(17.30)	(21.78)	(16.17)	(19.15)	(1.06)	0.290
Pizza size (mm ²)	118	6509.36	8328.46	10784.21	12521.33	5.61	<0.001*
Portion of chips (g)	118	25.33	38.43	21.83	26.26	-1.20	0.232
Portion of chocolate cake (mm ²)	118	30.56	36.35	29.62	36.52	0.82	0.415

* denotes $p < 0.05$

() Statistics once outliers are removed from the data set. The outliers were between 4 and 7 standard deviations above, and below, the mean.

7.4.6 Effects of food models on subjective appetite

To substantiate the claim that the food models used in this experiment provided a non-cued measure of participants' desired portion sizes, the effect of these models

on appetite was assessed by comparing ratings taken from before, to after, initial exposure to these models (i.e., when participants were indicating their pre-exposure desired portion sizes). In this experiment, this analysis was undertaken for the measures obtained both before, and after, lunch. Before lunch, the act of making pre-exposure portion-size selections using the food models significantly reduced fullness, increased desire-to-eat chips and pizza, and increased craving for all three test foods (Table 7.5). After lunch, although hunger increased significantly by approximately 3mm after indicating pre-exposure desired portion size of the test foods, desire-to-eat all the test foods was significantly reduced as was craving for pizza and chips (Table 7.6). By contrast, craving for chocolate cake and levels of fullness were not significantly different. Taken together, these findings suggest that the food models used in this experiment can in fact stimulate subjective appetite when participants have been deprived of food, but not after participants have recently eaten to satiety.

Table 7.5 Within-subject t-tests, means and standard deviations, for changes in hunger (mm) and fullness (mm), and changes in appetite ratings (desire to eat, and craving) (mm) for the cued (pizza), and non-cued (chips, and chocolate cake), foods after pre-exposure portion-size selections, while participants were hungry

		Before portion-size selection		After portion-size selection		<i>t</i> -value and significance	
	<i>n</i>	Mean	SD	Mean	SD	<i>t</i>	<i>p</i>
<i>Changes</i>							
Hunger (mm)	118	64.57	20.79	66.87	23.48	1.76	0.081
Fullness (mm)	118	14.02	17.03	16.87	17.51	2.66	0.009*
<i>Desire-to-eat</i>							
Pizza (mm)	118	53.97	29.26	57.80	29.71	2.45	0.016*
Chips (mm)	118	43.78	29.50	49.88	29.42	3.23	0.002*
Chocolate cake (mm)	118	51.81	26.65	52.97	29.65	0.743	0.459
<i>Craving</i>							
Pizza (mm)	118	42.53	29.89	51.56	31.47	5.72	<0.001*
Chips (mm)	118	36.46	28.48	44.74	30.01	4.71	<0.001*
Chocolate cake (mm)	118	43.58	28.96	50.23	29.43	4.30	<0.001*

* denotes $p < 0.05$

Table 7.6 Within-subject t-tests, means, and standard deviations, for changes in hunger (mm) and fullness (mm), and changes in appetite ratings (desire to eat, and craving) (mm) for the cued (pizza), and non-cued (chips, and chocolate cake), foods after pre-exposure portion-size selections in the absence of hunger

		Before portion-size selection		After portion-size selection		<i>t</i> -value and significance	
	<i>n</i>	Mean	SD	Mean	SD	<i>t</i>	<i>p</i>
Changes							
Hunger (mm)	118	11.81	11.81	14.09	13.99	2.54	0.013*
		(11.61)	(11.67)	(13.47)	(12.32)	(2.32)	(0.022)*
Fullness (mm)	118	73.12	16.87	72.79	19.10	-0.31	0.754
Desire-to-eat							
Pizza (mm)	118	20.45	21.06	15.99	20.04	-5.17	<0.001*
Chips (mm)	118	16.25	17.95	13.27	18.61	-3.35	0.001*
Chocolate cake (mm)	118	21.00	20.74	19.33	21.65	-5.17	<0.001*
Craving							
Pizza (mm)	118	17.97	21.24	14.76	20.67	-3.34	0.001*
		(17.43)	(20.52)	(14.73)	(20.75)	(-3.28)	(0.001)*
Chips (mm)	118	14.33	18.81	11.23	17.06	-3.40	0.001*
Chocolate cake (mm)	118	18.07	20.68	17.76	22.25	-0.28	0.780

* denotes $p < 0.05$

() Statistics once outliers are removed from the data set. The outliers were over 5.13 standard deviations above the mean.

7.4.7 Associations between food-cue reactivity and sensitivity to reward

Before lunch, pizza-cue exposure was not found to significantly stimulate greater hunger, a greater subjective appetite for the test foods (pizza, chips, or chocolate cake), or to increase desired portion size of any of the foods in individuals with a high sensitivity to reward (Table 7.7). In addition to this, a higher reward sensitivity was not associated with greater decreases in fullness following cue exposure before lunch. This was the case even after the removal of an outlier from the data set which was 5.61 standard deviations above the mean and 6.34 standard deviations above the predicted value from the linear regression model.

Again, after lunch, there was little evidence to suggest that individuals with higher reward sensitivities experienced greater changes in hunger, or fullness, or in subjective appetite (desire to eat and craving) for the pizza or for non-cued foods after cue exposure (Table 7.8). However, there was a statistically significant association between change in desired pizza size and sensitivity to reward scores when individuals were tested in the absence of hunger. Individuals with high sensitivity to reward scores experienced a change in desired pizza size of approximately 170kcal while those with lower scores on this scale experienced a change of approximately only 60kcal (see Figure 7.1). Table 7.9 provides estimates of how these changes might affect the *total* amount of pizza in Kcalories that individuals with different reward sensitivities might consume after cue exposure.

To determine the extent to which the association between sensitivity to reward scores and change in desired pizza size was independent of impulsivity scores, these scores were entered as a covariate into the regression model. This analysis suggested that the association between change in desired portion size and sensitivity to reward remained statistically significant even after controlling for impulsivity scores ($B = 393.15$, $SE = 195.03$, $p = 0.046$). This suggests that individuals with high reward sensitivities experienced a significantly greater change in desired portion after cue exposure irrespective of their tendency to act on impulse.

Table 7.7 Adjusted parameter estimates¹ from linear regression models for associations between sensitivity to reward scores and measures of cue reactivity before lunch

		<i>Sensitivity to reward</i>		
	<i>n</i>	<i>B</i>	<i>SE</i>	<i>p</i>
<i>Cue reactivity measure</i>				
Change in hunger	118	0.23	0.26	0.39
Change in fullness	118	0.05	0.22	0.80
		(-0.77)	(-0.13)	(0.44)
Change in desire-to-eat pizza	118	-0.01	0.41	0.98
Change in desire-to-eat chips	118	0.03	0.35	0.92
Change in desire-to-eat chocolate cake	118	0.16	0.37	0.66
Change in craving for pizza	118	-0.08	0.48	0.87
Change in craving for chips	118	0.14	0.43	0.75
Change in craving for chocolate cake	118	-0.54	0.37	0.15
Change in desired portion of pizza	118	502.95	307.24	0.10
Change in desired portion of chips	118	-0.82	0.64	0.20
Change in desired portion of chocolate	118	-0.66	0.64	0.31

¹ Adjusted for the relevant pre-exposure rating for all outcome measures, and adjusted for liking for the cued/non-cued food for food-specific outcome measures (e.g., change in craving for pizza, desired portion size of pizza)

() Statistics once outliers are removed from the data set. The outlier was 5.61 standard deviations above the mean and 6.34 standard deviations above the predicted value.

* denotes $p < 0.05$

Table 7.8 Adjusted parameter estimates¹ from linear regression models of associations between sensitivity to reward scores and measures of cue reactivity after lunch

		<i>Sensitivity to reward</i>		
	<i>n</i>	<i>B</i>	<i>SE</i>	<i>p</i>
<i>Cue reactivity measure</i>				
Change in hunger	118	0.37	0.31	0.234
Change in fullness	118	-0.19	0.32	0.567
		(-0.07)	(0.26)	(0.779)
Change in desire-to-eat pizza	118	0.34	0.44	0.433
		(0.42)	(0.40)	(0.293)
Change in desire-to-eat chips	118	0.20	0.21	0.361
		(0.12)	(0.19)	(0.539)
Change in desire-to-eat chocolate cake	118	0.55	0.32	0.089
		(0.47)	(0.29)	(0.109)
Change in craving for pizza	118	0.19	0.44	0.275
		(0.13)	(0.40)	(0.156)
Change in craving for chips	118	0.16	0.14	0.271
Change in craving for chocolate cake	118	0.24	0.26	0.365
		(0.17)	(0.24)	(0.477)
Change in desired portion of pizza	118	441.61	188.49	0.021*
Change in desired portion of chips	118	0.04	0.37	0.922
Change in desired portion of chocolate	118	35.37	19.97	0.079

¹ Adjusted for the relevant pre-exposure rating for all outcome measures, and adjusted for liking for the cued/non-cued food for food-specific outcome measures (e.g., change in craving for pizza, desired portion size of pizza)

() Statistics once outliers are removed from the data set. These outliers were between 4 and 7 standard deviations above and below the mean and between 3.5 and 6.5 standard deviations above and below the values predicted from the regression model.

* denotes $p < 0.05$

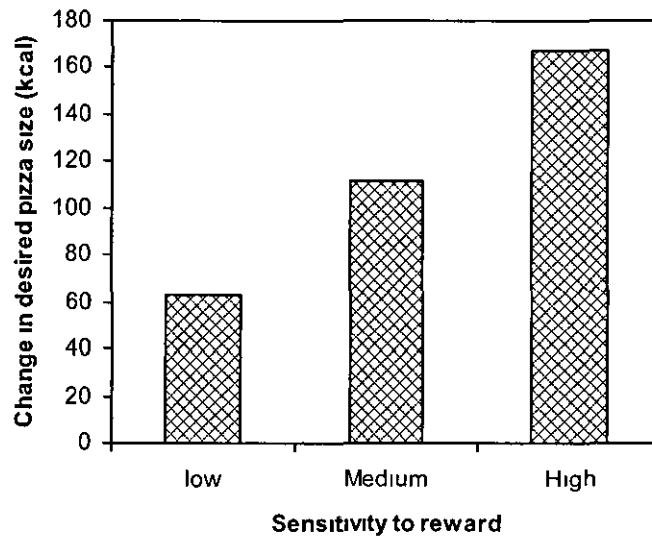


Figure 7.1 Predicted changes in desired pizza size (kcal) after lunch for individuals with low (7.23), medium (11.28), and high (15.95), sensitivity to reward scores from a regression model used to predict this measure ($B = 441.61$)¹⁵

Table 7.9 Predicted pre-exposure pizza size and calculated post-exposure portion size after lunch for individuals with low (7.23), medium (11.28), and high (15.95), sensitivity to reward scores¹⁶

	Pre-exposure (kcal)	Post-exposure (kcal)
<i>Sensitivity to reward scores</i>		
Low	144.17	207.80
Medium	174.23	286.16
High	208.80	376.29

¹⁵ Liking for pizza and pre-exposure desired pizza size were held at their average values in the sample (73.05mm and 6509.36mm² [175.75 kcal]) and their respective parameter estimates from the regression model [$B = 95.35$ and $B = 0.095$, respectively] were used to predict desired portion size of pizza for individuals with a low, medium, and high sensitivity to reward

¹⁶ Pre-exposure size is predicted from a regression model used to predict this measure ($B = 274.83$). Average liking for pizza was held at its average value in the sample (73.05) and its parameter estimate from the regression model was used to predict pre-exposure portion size ($B = 49.10$). Post-exposure portion size was calculated from this measure by summing the predicted pre-exposure portion sizes to the predicted change in desired pizza size

7.4.8 Associations between food-cue reactivity and impulsivity

7.4.8.1 Stop start task

There was little evidence to suggest that stop start signal scores were associated with changes in any of the measures of subjective appetite, or portion-size selection, after cue exposure either in the absence of hunger (after lunch), or after four hours food deprivation (all $p > 0.05$) (Results not shown here because they all failed to reach statistical significance). However, there were limitations associated with this measure. These will be discussed further in the discussion (Section 7.5).

7.4.8.2 EPQ-impulsivity scores

Before lunch, there was little evidence to suggest that impulsivity scores were associated with changes in general subjective appetite (hunger and fullness) after cue exposure, or with increased motivation-to-eat (subjective appetite and desired portion size selections) the non-cued foods (Table 7.10). However, there was evidence of a statistically significant association between these scores and change in craving for pizza (Table 7.10). As Figure 7.2, Panel A suggests change in craving for pizza was greater in individuals who reported greater impulsivity. Before lunch, these individuals were also found to select significantly larger pizza sizes after cue exposure (see Table 7.10, and Figure 7.2, Panel B). Table 7.11 provides estimates of the effect of these increases on the *total* amount of pizza that these individuals might consume after cue exposure.

To determine the extent to which these associations observed between impulsivity scores and the two measures of cue reactivity (change in craving and change in portion-size selection) before lunch were independent of sensitivity to reward both predictor variables were entered simultaneously into two separate regression models to predict change in craving for pizza/ change in pizza portion size as outcomes. This analysis suggested that the association between change in craving and

impulsivity scores remained statistically significant ($B = 1.05$, $SE = 0.45$, $p = 0.022$), suggesting that individuals with higher impulsivity scores experienced a greater change in craving for pizza after cue exposure irrespective of their sensitivity to reward. However, the association between impulsivity scores and change in desired portion size was no longer statistically significant when sensitivity to reward was also entered into the regression model ($B = 556.82$, $SE = 295.89$, $p = 0.062$). This suggests that impulsivity scores were not independently associated with the changes in desired pizza size observed and that these changes were in fact explained by some shared variance between impulsivity and sensitivity to reward scores. Indeed, visual inspection of Figure 7.3 suggests that although individuals with high impulsivity scores in the absence of a high sensitivity to reward did experience greater changes in desired pizza than those with lower scores on both scales, individuals who had simultaneously high scores on the impulsivity and sensitivity to reward scales experienced the greatest increase in desired pizza after cue exposure.

Table 7 10 Adjusted parameter estimates¹ from linear regression models for associations between impulsivity scores and measures of cue reactivity before lunch

	Impulsivity			
	<i>n</i>	<i>B</i>	<i>SE</i>	<i>p</i>
<i>Cue reactivity measures</i>				
Change in hunger	118	0.33	0.24	0.164
Change in fullness	118	-0.25	0.24	0.302
		(0.26)	(0.22)	(0.237)
Change in desire-to-eat pizza	118	0.59	0.37	0.111
Change in desire-to-eat chips	118	-0.44	0.33	0.184
Change in desire-to-eat chocolate cake	118	-0.04	0.34	0.897
Change in craving for pizza	118	0.88	0.42	0.039*
Change in craving for chips	118	-0.59	0.40	0.142
Change in craving for chocolate cake	118	-37	0.06	0.856
Change in desired portion of pizza	118	647.72	271.39	0.019*
Change in desired portion of chips	118	-0.32	0.58	0.589
Change in desired portion of chocolate cake	118	15.84	45.62	0.729

¹ Adjusted for the relevant pre-exposure rating for all outcome measures, and adjusted for liking for the cued/non-cued food for food-specific outcome measures (e.g., change in craving for pizza, desired portion size of pizza)

() Statistics once outliers are removed from the data set. The outlier was 5.61 standard deviations above the mean and 4.88 standard deviations above the values predicted from the regression model.

* denotes $p < 0.05$

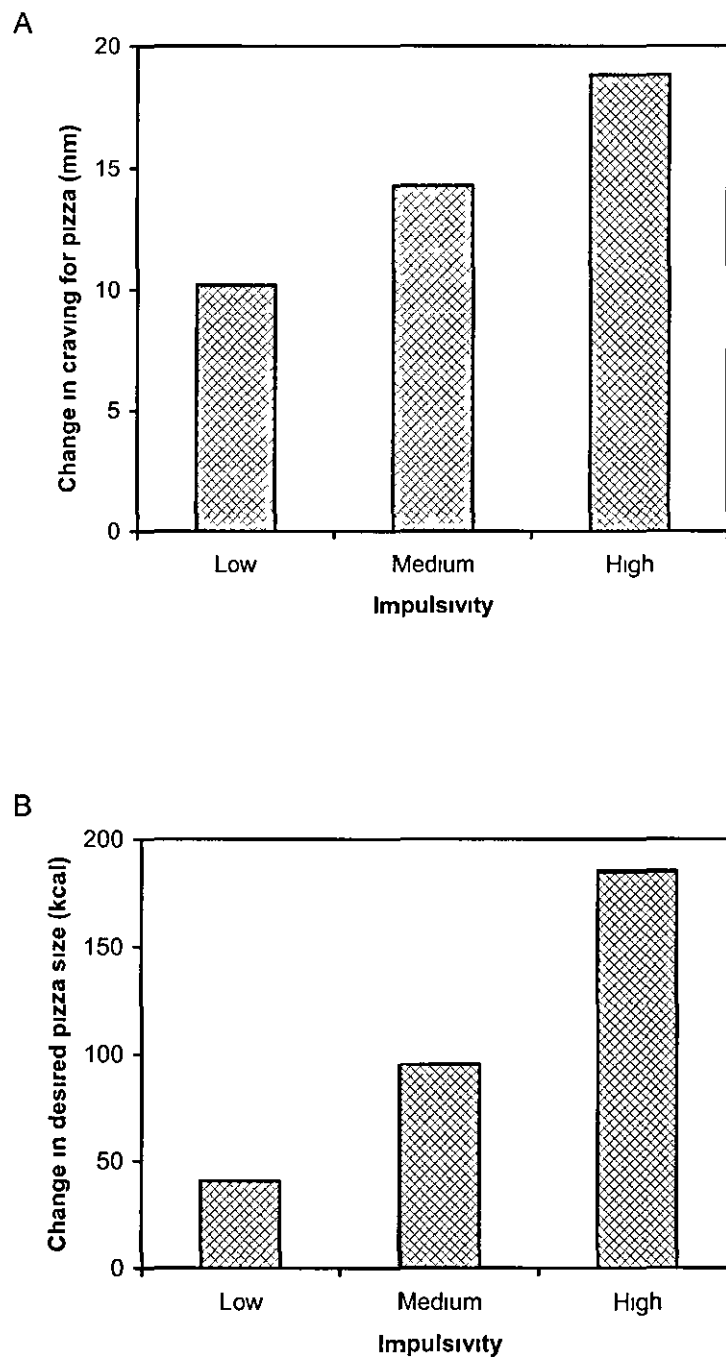


Figure 7.2 Predicted changes in craving for pizza (mm) (A) and desired pizza size (kcal) (B) before lunch for individuals with low (2.82), medium (7.49), and high (12.65), impulsivity scores from a regression model used to predict these measures ($B = 0.88$, $B = 647.72$, respectively)¹⁷

¹⁷ Liking for pizza (73.05mm), and pre-exposure craving for pizza (50.56 mm), were held at their average values in the sample for predicted changes in craving for pizza and their parameter estimates from the regression model were used to predict pre-exposure portion size ($B = 0.14$, $B = -0.29$, respectively) For predicted changes in desired pizza size liking for pizza (73.05mm) and pre-exposure desired pizza size (30582.91 [825.74 kcal]) were held at their average value in the sample

Table 7.11 Predicted pre-exposure pizza size and calculated post-exposure portion size after lunch for individuals with low (2.82), medium (7.49), and high (12.65), impulsivity scores¹⁸

Impulsivity scores	Pre-exposure (kcal)	Post-exposure (kcal)
Low	807.60	848.43
Medium	822.11	917.15
High	838.15	1023.43

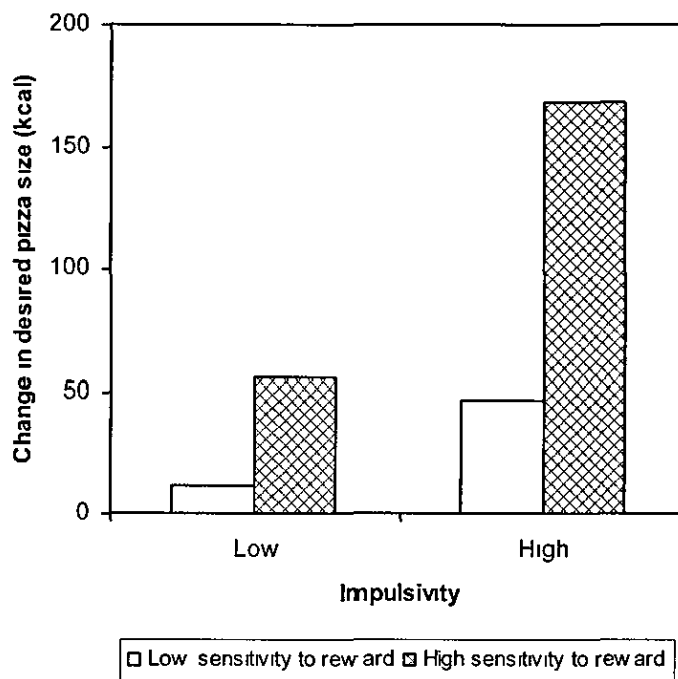


Figure 7.3 Predicted changes in desired pizza size (kcal) for individuals with low (3.93)/high (11.25) impulsivity and low (8.17)/high (14.43) sensitivity to reward from a regression model used to predict change in desired pizza size before lunch¹⁹

and their parameter estimates from the regression model were used to predict pre-exposure portion size ($B = 78.09$, $B = -0.04$, respectively)

¹⁸ Pre-exposure size is predicted from a regression model used to predict this measure while holding average liking for pizza at its average value in the sample (73.05). Post-exposure portion size was calculated from this measure using predicted change in desired pizza size after controlling for liking for pizza and pre-exposure portion size.

¹⁹ Liking for pizza and pre-exposure desired pizza size were held at their average values in the sample (73.05mm and 30582.91mm² [825.74 kcal]).

After lunch, individuals with high impulsivity scores experienced greater changes in desire-to-eat pizza, craving for this food, and hunger (see Table 7.12 and Figure 7.4). These associations remained statistically significant after controlling for sensitivity to reward (all $p < 0.05$). However, it is important to note that after including the two outliers described earlier in the analysis (see data analysis section, 7.3.6), the association between change in hunger and impulsivity was no longer statistically significant after controlling for sensitivity to reward ($B = -0.57$, $SE = 0.30$, $p = 0.063$).

Visual inspection of the association between impulsivity scores and change in desired portion size of pizza revealed a curved rather than linear association. For this reason, impulsivity scores were split at their median value in the sample and entered into the regression model as a discrete variable. However, this model provided little evidence to suggest that impulsive individuals experienced a greater change in desired portion of the cued food than less impulsive individuals (Table 7.12).

Table 7.12 Adjusted parameter estimates¹ from linear regression models for associations between impulsivity scores and measures of cue reactivity after lunch

		<i>Impulsivity</i>		
	<i>n</i>	<i>B</i>	<i>SE</i>	<i>p</i>
<i>Cue reactivity measures</i>				
Change in hunger	118	0.63	0.28	0.028*
Change in fullness	118	-0.154	0.29	0.602
		(-0.15)	(0.24)	(0.520)
Change in desire-to-eat pizza	118	1.05	0.39	0.008*
		(1.06)	(0.36)	(0.004)*
Change in desire-to-eat chips	118	0.07	0.19	0.725
		(0.09)	(0.50)	(0.618)
Change in desire-to-eat chocolate cake	118	0.04	0.30	0.991
		(0.03)	(0.27)	(0.905)
Change in craving for pizza	118	1.16	0.40	0.004*
		(1.16)	(0.36)	(0.002)*
Change in craving for chips	118	0.11	0.13	0.371
Change in craving for chocolate cake	118	0.03	0.24	0.989
		(0.01)	(0.22)	(0.948)
Change in desired portion of pizza ²	118	2333.51	1537.72	0.132
Change in desired portion of chips	118	0.24	0.24	0.478
Change in desired portion of chocolate cake	118	-5.68	18.55	0.760

¹ Adjusted for the relevant pre-exposure rating for all outcome measures, and adjusted for liking for the cued/non-cued food for food-specific outcome measures (e.g., change in craving for pizza, desired portion size of pizza)

² Impulsivity scores were split at their median value in the sample to explore the association with this outcome measure because this association was not linear

() Statistics once outliers are removed from the data set. These outliers were between 4 and 7 standard deviations above and below the mean and between 3.5 and 6.5 standard deviations above and below the values predicted from the regression model

* denotes $p < 0.05$

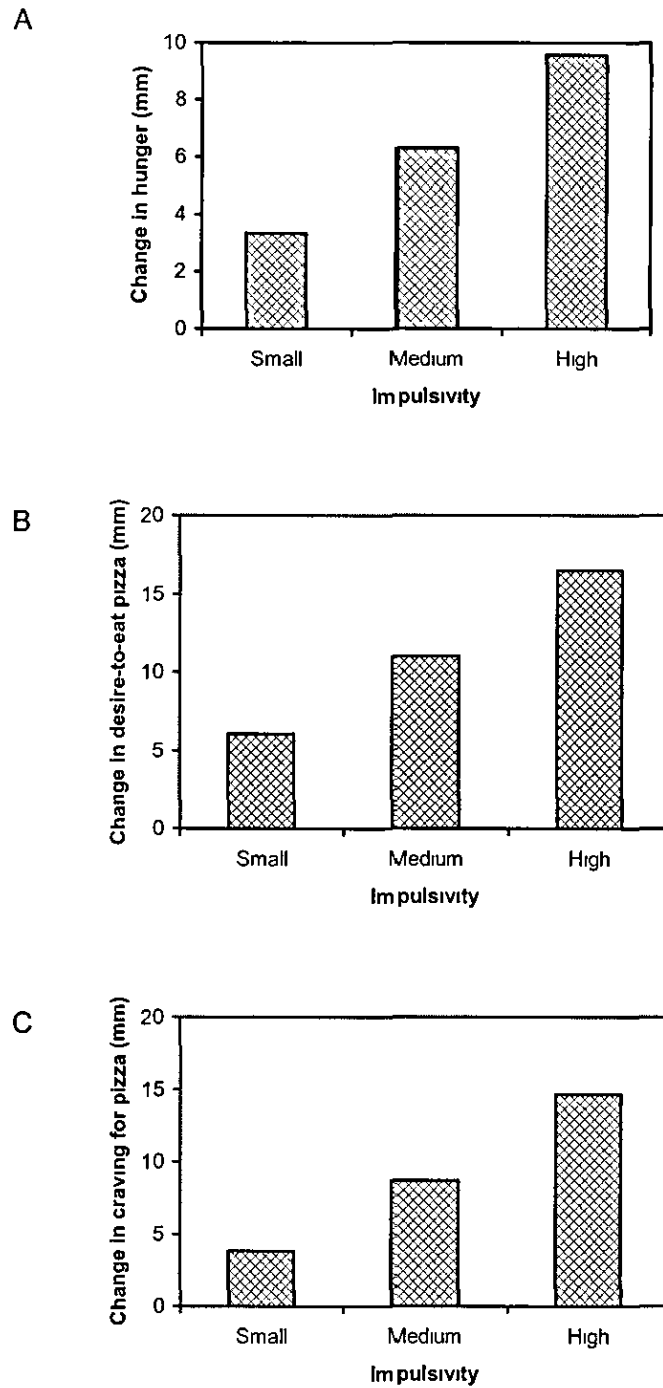


Figure 7.4 Predicted changes in hunger (mm) (A), desire-to-eat pizza (mm) (B), and craving for pizza (mm) (C) after lunch for individuals with small (2.82), medium (7.49), and high (12.65), impulsivity scores from three regression models used to predict these measures ($B = -0.633, 1.049, 1.159$, respectively)²⁰

²⁰ Pre-exposure hunger (14.09) ($B = -0.247$), desire-to-eat (15.99mm) ($B = -0.264$), and craving for pizza (14.76mm) ($B = -0.244$) were held at their average value in the relevant models. Liking for pizza (73.05mm) was held at his average value in the sample when predicting change in desire-to-eat, and craving for, pizza ($B = 0.236, B = 0.288$, for change in desire to eat, and craving for, pizza, respectively)

7.4.9 Associations between cue reactivity, everyday dietary behaviour, and body weight

There was little evidence to suggest that changes in general measures of subjective appetite (hunger and fullness), changes in subjective appetite for the cued and non-cued foods, and changes in desired portion sizes of these foods were associated with DEBQ-restraint scores, TFEQ-disinhibition scores, or being overweight (all $p > 0.05$).

Notably, preliminary observations of the association between change in desired pizza size and TFEQ-disinhibition scores suggested that the relationship was curved rather than linear. For this reason, TFEQ-disinhibition scores were split at their median value in the sample for the subsequent regression analysis. Notably, these preliminary observations also suggested that the variance in change in desired portion size increased as TFEQ-disinhibition increased (homoscedascity). Thus, some individuals with high disinhibition scores were selecting much larger portions of pizza after cue exposure than those selected by individuals with lower scores on this scale, while other individuals with high disinhibition scores were selecting portion sizes similar to those selected by less disinhibited individuals. This suggested that another variable might be interacting with disinhibition scores to explain elevated cue reactivity in a subsection of the individuals with high disinhibition scores. To explore this possibility, interactions between disinhibition scores (high/low) and i) dietary restraint, ii) BMI, iii) sensitivity to reward, and iv) impulsivity (high and low) were assessed using regression analyses which controlled for liking for pizza and pre-exposure desired portion size. However, the only interaction which reached statistical significance was that between disinhibition scores (high/low) and impulsivity scores (high/low) ($B = 7908.11$, $SE = 3174.25$, $p = 0.014$). As Figure 7.5 suggests cue exposure had a much greater effect on desired portion size for individuals with simultaneously high scores on the disinhibition scale and impulsivity scale. For all other individuals, change in desired portion size was relatively similar although individuals with low impulsivity and low disinhibition scores did experience a modestly greater change in desired pizza

size²¹ It is important to note that this interaction remained statistically significant even after controlling for restraint status ($B = 8942.94$, $SE = 3234.65$, $p = 0.007$) and after controlling for sensitivity to reward ($B = 8315.62$, $SE = 3133.16$, $p = 0.009$). This suggests that change in desired pizza size was elevated in individuals with simultaneously high impulsivity and disinhibition scores irrespective of their restraint status or their sensitivity to reward scores.

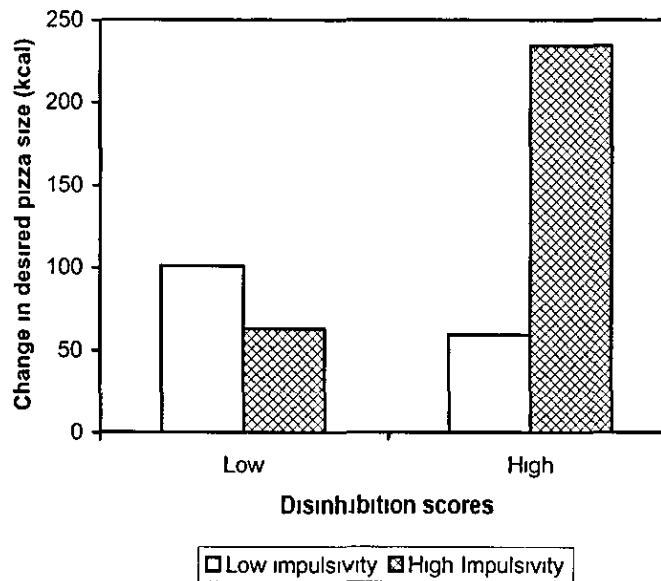


Figure 7.5 Predicted changes in desired pizza size (kcal) after lunch for individuals with different combinations of TFEQ-disinhibition scores and impulsivity scores based on parameter estimates from regression models²²

²¹ This interaction was not evident when individuals were hungry ($p > 0.05$)

²² In these models liking for pizza and pre-exposure desired pizza size were held at their average values in the sample (73.05mm and 6509.36mm² [175.75 kcal])

Again it was desirable to determine the effect of these changes experienced by individuals with simultaneously high disinhibition, and impulsivity, scores on *total* desired portion in Kcalories after cue exposure. Estimates of these post-exposure portion sizes were calculated from the sum of the pre-exposure portion-size selections and the change in these portion sizes (see section 7.3.6 data analysis for further details of this procedure). This calculated post-exposure total portion size and the predicted pre-exposure portion size are displayed in Table 7.13. This table suggests that after cue exposure the *total* desired portion size was almost identical for individuals with high disinhibition scores irrespective of their impulsivity scores. This implies that the greater change experienced by individuals with simultaneously high scores on the disinhibition scale and impulsivity scale did not result in these individuals selecting a larger portion size in total after cue exposure. The reason these individuals' greater change in portion did not result ultimately in the selection of a larger total portion size after cue exposure is because they selected much smaller portion sizes prior to cue exposure (see Table 7.13). After controlling statistically for liking for pizza, the interaction effect between disinhibition scores (high and low) and impulsivity scores (high and low) for these pre-exposure measures reached statistical significance ($B = -10607.50$, $SE = 2999.91$, $p = 0.001$). This suggests that individuals with high disinhibition scores selected much smaller pre-exposure portion sizes if they had high impulsivity scores relative to if they had lower impulsivity scores. By contrast, individuals with low scores on this scale selected much larger pre-exposure portion sizes if they had high impulsivity scores relative to if they had lower impulsivity scores. The reason for these differences in pre-exposure portion-size selections is unclear. However, one possibility is that this interaction effect results from the fact that those individuals who selected larger pre-exposure portion sizes did so because they were relatively hungrier following the buffet lunch. To explore this possibility, the interaction between impulsivity and disinhibition scores was assessed for hunger ratings made immediately prior to these portion-size selections. This analysis revealed a significant interaction effect ($B = -10.66$, $SE = 4.47$, $p = 0.019$). As suggested by Table 7.14 the interaction effect was identical to that observed for pre-exposure portion size. Thus, individuals with high disinhibition scores reported lower hunger levels if they had high impulsivity scores relative to if they had

lower impulsivity scores. By contrast, individuals with low scores on this scale reported greater levels of hunger if they had high impulsivity scores relative to if they had lower impulsivity scores. In Table 7.14 the pre-exposure portion-size selections for these groups of individuals can be seen in brackets. Direct comparison of these portion sizes suggests that those individuals who selected the larger pre-exposure portion sizes were in fact hungrier. Given the fact that individuals across the four groups appeared to differ in hunger prior to cue exposure, it was recognized that it was important to control statistically for hunger levels prior to cue exposure in the regression model used to explore the interaction between impulsivity (high and low) and disinhibition scores (high and low). This interaction remained statistically significant even after controlling for this pre-exposure hunger ($B = 7521.19$, $SE = 3212.90$, $p = 0.021$)

*Table 7.13 Predicted pre-exposure pizza size and calculated post-exposure portion size for individuals with different combinations of TFEQ-disinhibition scores and impulsivity scores*²³

	Low Impulsivity		High Impulsivity	
	Pre-exposure (kcal)	Post-exposure (kcal)	Pre-exposure (kcal)	Post-exposure (kcal)
Low Disinhibition	78.43	179.25	214.37	273.44
High Disinhibition	305.09	367.82	132.97	367.46

²³ Pre-exposure size is predicted from a regression model used to predict this measure while holding average liking for pizza at its average value in the sample (73.05mm). Post-exposure size was then calculated by adding the change in desired portion size predicted from the linear regression after controlling for liking for pizza and the pre-exposure portion size.

Table 7.14 Predicted hunger ratings (mm) prior to the pre-exposure portion-size selection based on the parameter estimates from the regression model²⁴

	Low Impulsivity	High Impulsivity
Low Disinhibition	8.381 (78.43)	16.51 (214.37)
High Disinhibition	13.39 (305.09)	10.86 (132.97)

7.4.10 Awareness Questionnaire

The responses from the awareness questionnaire issued in the final stages of the experiment are summarised in Table 7.15. These responses indicate that there were a small number of participants who provided responses to a general question enquiring about the aims of the study which indicated they might have some awareness of the purpose of this experiment (13.7%), and an even smaller percent (6%) were aware of the reason for the lunch manipulation. However, approximately a quarter of the sample appeared to be aware of the experiment's aim to assess the effect of cue exposure on appetite ratings and desired portion-size selections. In light of this finding, a series of regression analyses were conducted in which awareness was entered as a predictor of the key outcome measures considered in this experiment (change in an appetite ratings and portion-size selection) when individuals were hungry and satiated²⁵. However, these analyses did not provide evidence to suggest that the outcome measures differed across aware, and non-aware, participants (all associations $p > 0.05$). Furthermore, a series of between-subject t-tests and a chi-squared test for the categorical variable BMI

²⁴ Predicted pre-exposure portion sizes were based on the parameter estimates from a regression model used to predict this measure

²⁵ In these analyses corresponding pre-exposure measures were controlled for statistically, as was liking for pizza where the outcome measure was pizza specific

provided little evidence to suggest that awareness differed across the six predictor variables (dietary restraint, disinhibition, body weight, BAS-trait, EPQ-impulsivity, or the stop start signal task).

Table 7.15 Summary of responses to the awareness questionnaire. All totals are given in percentages.

Question	Response (%)	
	Aware	Not aware
1. What do you think was the purpose of this experiment?	13.7	86.3
2. I asked you to rate your mood and appetite during the experiment. Do you know why?	21.5	78.5
3. I asked you to indicate the amounts of pizza, chocolate cake, and chips that you would like to eat at various times during the experiment. Do you know why?	21.5	78.5
4. I expected you to want to eat greater amounts of these foods than you might normally do		
a) Which time (first, second, third, fourth)?	49.1	50.9
b) Which food (pizza, chips, chocolate cake)?	69.8	30.2
5. Do you know why you were offered lunch in this experiment?	6	94

7.4.11 Summary table of main results

Given the complexity of the results described here, this section provides a tabular summary of the observed associations between the predictor, and the outcome, variables. This table (Table 7.16) suggests that dietary restraint, dietary disinhibition, and being overweight were not significant predictors of any of the measures of food-cue reactivity. However, it does suggest that sensitivity to reward, impulsivity, and an interaction effect between dietary disinhibition and impulsivity might be important predictors of some of the measures of change in appetite for the cued food.

Table 7.16 Summary of the significant associations between the predictor variables and the main outcome variables

	Predictor variables					
	Restraint	Disinhibition	Being overweight	BAS trait	Impulsivity	Impulsivity* disinhibition
<i>Outcome measures</i>						
Change in hunger					✓ ²	
Change in fullness						
Change in desire-to-eat pizza					✓ ²	
Change in desire-to-eat chips						
Change in desire-to-eat chocolate cake						
Change in craving for pizza					✓ ^{2 1}	
Change in craving for chips						
Change in craving for chocolate cake						
Change in desired pizza portion				✓ ²	✓ ^{1 *}	✓ ²
Change in desired portion of chips						
Change in desired portion of chocolate cake						

✓ Denotes where statistically significant interactions were observed

¹ Association observed before lunch

² Association observed after lunch

* This was no longer statistically significant after controlling for sensitivity to reward (i.e., BAS trait)

7.5 Discussion

The primary aim of this experiment was to determine the extent to which individual differences in the functioning of a hypothesised brain system, the BAS, and differences in impulsivity, might be associated with food-cue reactivity in two different motivational states (food deprived and non-food deprived). Given that the BAS is assumed to respond to stimuli associated with a reward, it was hypothesised that greater

reactivity of this system might predict the occurrence of greater appetitive motivation elicited by a food cue. The results from this experiment suggested that in a non-food deprived state there was little evidence that those individuals with a high BAS trait (i.e., a high sensitivity to reward), experienced greater changes in subjective appetite for cued, or non-cued, foods or selected larger portions of these foods after cue exposure. However, after lunch, although individuals with a high BAS trait were not found to experience a greater increase in subjective appetite for the cued food relative to those individuals with a lower BAS trait, they did experience a greater change in desired portion size of this food.

Therefore, in part, the findings from the present study are consistent with Gray's (1970, 1976, 1981, 1987a, 1987b) predictions regarding the functioning of the BAS. This is because Gray (1970, 1976, 1981, 1987a, 1987b) would predict that individuals with a high BAS trait experience greater appetitive motivation for cued stimuli which are associated with a reward. Notably, however, the present findings are not the first to provide support for this theory. Rather, two recent studies have also suggested that after exposure to a drug cue, motivation to use drugs is greater in those individuals with a higher BAS trait (Kambouropoulos, & Staiger, 2001; 2004). The importance of this accumulating evidence in support of a BAS-like system is that it raises the possibility that all behaviour that is motivated by external cues signaling a reward is the result of reactivity of one universal system. This possibility implies that individual differences in food-cue reactivity (and drug-cue reactivity for that matter) do not result from individual differences specific to that particular behaviour (i.e., eating, or drug use), but rather result from a more general tendency to experience a greater appetitive motivation in the presence of cues signaling a potential reward. An important, yet obvious, consequence of this is that individuals who experience greater sensitivity to food cues are also likely to experience greater sensitivity to other cues in the environment that signal a reward.

Given that food-cue reactivity might result from activation of a universal approach system sensitive to cues signaling a reward, it is important to begin to understand the

mechanism underlying this system. One possibility is that greater sensitivity to stimuli associated with rewards in those with highly reactive BAS's results from stronger associations between these stimuli and the primary reinforcer (or reward) (Pickering & Gray, 2001). For example, individuals who are more reactive to food cues might form stronger associations between the sight and smell of food and a tasty reward. However, empirical support for this possibility has been weak. For example, several studies have found that those with higher BAS reactivity do not form associations between a stimuli and a primary reward at a greater rate than those with a lower BAS reactivity. Rather, these studies have found that once these responses are learnt, individuals with a high BAS trait perform them faster (Corr, Pickering, & Gray, 1995, Pickering, Diaz, & Gray, 1995). For this reason, Pickering and Gray (2001) suggest that rather than forming stronger learned associations between external stimuli (e.g., a food cue) and a reward (i.e., the tasty reward), those with higher BAS activity might in fact attribute greater '*incentive salience*' to a conditioned stimulus (CS). The implication of this is that when these individuals are exposed to this stimulus on subsequent occasions the salience of the incentive offered by this stimulus is greater for these individuals.

The notion of motivated responses relying on incentive salience is consistent with Berridge and Robinson's (1998) Incentive Salience hypothesis. To recap, this hypothesis was described in Chapter 2 and suggests that the ability of an external cue (such as a food cue) to motivate behaviour is the result of three psychological processes. Initial contact with an unconditioned stimulus (i.e., a tasty food) produces a hedonic liking for the food and thereby leads to the acquisition of new incentives. A correlation is then identified between this hedonic activation and the external stimulus that predicted it. Finally, this external stimulus acquires incentive salience, and thereby is able to command attention and elicit a motivational state. This final stage is the most important stage and is necessary for food-cue reactivity to occur. Initial contact with a food cue alone will not result in greater reactivity. Thus, it is this final stage which Pickering and Gray (2001) suggest might differ in those individuals with a highly reactive BAS. This is because those with a higher BAS are assumed to attribute greater incentive salience to a food cue.

Importantly, in their Incentive Salience hypothesis, Berridge and Robinson (1998) suggest that incentive salience is attributed via dopamine activation. Put simply, it is assumed that when individuals are presented with a stimulus that predicts a reward, dopaminergic activity begins and thereby incentive salience is attributed to this stimulus. Berridge and Robinson (1998) present a review of evidence suggesting that disruption of dopaminergic activity (which has been found to occur in anticipation of a reward) does not affect learned associations themselves, but rather disrupts appetitive motivation for the CS. The authors use this evidence to suggest that dopamine is required for incentive salience, but is not necessary for the formation of associations between an external stimuli and the reward it predicts. This is potentially relevant to understanding the mechanism underlying the BAS because it is also assumed that the functioning of the BAS depends on firing of dopamine cells (Pickering & Gray, 2001). Thus, one possibility is that those individuals with a highly reactive BAS experience greater dopamine firing in the presence of stimuli associated with rewards, thereby they attribute greater incentive salience to these stimuli, and for this reason are more motivated to obtain the reward associated with this cue. Given that evidence implicates dopamine as the determinant of cue-elicited behaviour (see Berridge & Robinson, 1998 for a review), it does follow that individual differences in dopamine activation might determine reactivity to environmental cues. However, the extent to which a high BAS trait predicts greater dopamine activation remains to be established. To date, evidence has only shown that behaviours associated with BAS activity are related to neurological disruptions which elicit greater dopamine activation (Comings, Gade, Wu, Chiu, Dietz, Muhlemann *et al* 1997). Therefore, future work is required to determine the extent to which a high BAS trait is associated with greater dopamine activation in the presence of cues associated with a reward. There is also a need to understand the extent to which these differences in dopamine activation determine appetitive motivation elicited by these stimuli.

Implicit in the preceding discussion is the notion that a high BAS trait is indiscriminately associated with a greater appetitive motivation in the presence of food

cues. However, the results from the present study suggest that a highly reactive BAS was not in fact associated with greater motivation to eat a cued food while individuals were food deprived. This suggests that individual variation in the BAS might only predict greater food-cue reactivity when individuals are satiated. The reason for this might not be that the BAS functions differently in different physiological states, but rather that a highly reactive BAS is not required to experience appetitive motivation for a stimuli associated with a food reward when a physiological drive to eat is present. Consistent with this possibility, it has been suggested that an entirely separate neural system (i.e., the tegmental pedunculopontine, TPP) mediates the incentive value of rewards when animals are in a deprived state (Bechara & van der Kooy, 198, 1992), thus suggesting that attribution of incentive salience is not required in order for a cue to motivate behaviour while food deprived. Berridge and Robinson (1998) suggest that this is because a motivational drive to eat is sufficient to motivate greater appetitive motivation in the absence of a high BAS trait. Therefore, following from this, in circumstances where individuals are deprived of food it is expected that physiological drive rather than a high BAS trait will predict food-cue reactivity. By contrast, on occasions where individuals are non-food deprived, i.e., satiated, the BAS would be expected to predict reactivity to food cues. Therefore, the implication of having a high BAS is that overeating will occur in the presence of food-related cues when energy from food is least required.

At this point it might also be worth noting further findings from this experiment which define the implications of having a high BAS trait for food-cue reactivity. Firstly, even in circumstances where individuals with a high BAS trait selected larger portions of the cued food relative to those individuals with a lower BAS trait, they did not select larger portions of the non-cued foods. This finding is perhaps not surprising given that when individuals with a highly reactive BAS are exposed to a food cue, the salience of the incentive offered by this food will increase, but the salience of the incentive offered by other foods will remain unchanged. Secondly, it is worth considering the implication of finding that the only measure of motivation-to-eat the cued food to increase to a greater extent in individuals with a high BAS trait relative to those with a lower BAS trait, was

the measure of desired portion size. Neither ratings of subjective appetite for this food, nor hunger, increased to a greater extent in these individuals. One possibility is that this greater appetitive motivation was not consciously experienced to a greater extent in these individuals and therefore was not reported. Berridge and Robinson (1998) suggest that the *attribution* of incentive salience is an unconscious process which can later become conscious. Thus, it is possible that the increased salience of the incentive offered by a food cue was also not consciously experienced. An alternative possibility, however, is that these appetite ratings were insensitive to the greater changes in appetitive motivation experienced by these individuals.

In addition to considering the role of the BAS trait in sensitivity to food cues, this experiment also explored the association between food-cue reactivity and impulsivity. Impulsivity was assessed using the EPQ-impulsivity scale, and using the Stop start signal task (a measure of inhibitory control). The results provided little evidence to suggest that higher scores obtained on the Stop start signal task were associated with a greater motivation to eat after cue exposure. Therefore, initially, this finding suggests that deficits in inhibitory control (i.e., deficits in the ability to inhibit impulses to act) are not implicated in food-cue reactivity. However, it is important to note that this task was not executed well in this experiment. Indeed, as suggested in the previous section, the mean score obtained on the task across the sample was relatively high in comparison to means obtained in a similar samples of participants by Nederkoorn *et al.* (2004). Inspection of the scores obtained in this study suggested that a proportion of the participants had been ignoring the stop signal and merely responding to the choice reaction-time task (go signal). To recap, the stop signal originally sounds 250ms after the go signal. If participants fail to inhibit their response to the go task, the sound is produced 50ms earlier in order to make it easier for the participants to inhibit their response. If the response is still not inhibited the delay of the stop signal will be reduced by a further 50ms on the subsequent trial. This reduction in the delay of the stop signal continues until the individual is able to inhibit their response to the choice reaction-time task ('go' task). However, if a participant is ignoring the stop signal and responding to the go signal on all trials, then the delay between the go signal and the

stop signal will be continuously reduced such that the stop signal in fact occurs before the go signal. This is the pattern of responses which were observed in a proportion of the participants in this experiment. One potential reason for the poor execution of this task might have been because the instructions were not well understood. Therefore, future studies which aim to use this task might benefit from ensuring that task instructions are well understood prior to the test phase, and by training participants on the task if deemed necessary.

In addition to using the stop start signal task as a measure of impulsivity in this experiment, the EPQ-impulsivity scale was also used. Unlike the stop start signal task, this scale provides a more general measure of tendencies to act on impulse across different situations. Using this scale, the results from this experiment suggest that impulsivity does play a role in food-cue reactivity. With regards to subjective appetite, after four hours food deprivation, individuals with a high degree of impulsivity experienced a greater increase in craving for pizza after cue exposure, irrespective of their sensitivity to reward. Likewise, immediately after eating to satiety, these individuals experienced a greater change in hunger, desire-to-eat pizza, and craving for this food. The results relating to change in desired portion size were slightly more complicated. Before lunch, although impulsivity was associated with change in desired portion size, this association was not statistically significant after controlling for sensitivity to reward scores. Observation of the data suggests that this might be because it is only those individuals who have simultaneously high sensitivity to reward and impulsivity scores who experience the greatest change in desired portion-size selection after cue exposure when deprived of food. Notably, a different pattern of results emerged after lunch for change in desired portion size of the cued food. In these circumstances, an interaction effect between impulsivity and dietary disinhibition suggested that only impulsive individuals who also have high disinhibition scores experience a greater change in desired portion-size selection after cue exposure. Therefore, taken together, these findings suggest that impulsivity alone is able to motivate greater subjective appetite for a cued food when individuals are both hungry and when they are satiated. However, they suggest that impulsivity might have to be

coupled with sensitivity to reward to motivate a greater change in desired portion size when individuals are hungry, and with high dietary disinhibition when individuals are satiated.

To interpret the observed role of impulsivity in food-cue reactivity, it is perhaps important to understand the implications of being impulsive. Recently, impulsivity has been defined as a predisposition towards rapid, unplanned, reactions to internal or external stimuli (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). Thus, given that a food cue constitutes an external stimulus, perhaps it is not surprising that impulsivity might be an important determinant of food-cue reactivity. Indeed, after food-cue exposure, impulsive individuals might make a rash decision to eat the cued food.

Previously, impulsivity has been found to share associations with everyday smoking (Grano *et al* , 2004; Mitchell, 1999), smoking relapse following 48-hours of nicotine abstinence (Doran *et al.*, 2004), frequency of alcohol consumption and the quantity consumed (Grau & Ortet, 1999, Grano *et al* , 2004, Waldeck & Miller, 1997), alcohol dependence symptoms, and methamphetamine abuse symptoms (Simons *et al* , 2005). However, this is the first study to associate impulsivity with greater reactivity to food cues. Therefore, the importance of these findings is that they suggest that, like substance use, food-cue reactivity might also be contingent upon a more general inability to resist reacting to external stimuli in the environment

It is interesting that the present findings perhaps suggest that impulsivity is not the sole factor that drives the desire to consume larger amounts after food-cue exposure. Indeed, one important finding was that suggesting that impulsive individuals with a greater sensitivity to reward appear to experience the *greatest* changes in desired portion size after cue exposure when they are mildly food deprived (i.e., four-hour food deprived). This is a particularly interesting result given that previously in this discussion it was suggested that sensitivity to reward is unable to motivate a desire for larger portion sizes of a cued food when individuals have been deprived of food. However, perhaps

paired with greater impulsivity, a greater sensitivity to reward is able to elicit a desire for a larger portion size of a cued food when individuals are food deprived. Indeed, given that individuals with a heightened sensitivity to reward presumably attribute greater incentive salience to food cues (Pickering & Gray, 2001), it is possible that in the presence of stimuli signaling a tasty reward, impulsive individuals with a high sensitivity to reward are unable to resist the temptation offered by the tasty reward. Therefore, these individuals desire the largest portion size of the cued food. By contrast, in the absence of a high BAS trait, a food cue is unlikely to predict the same intense indication of a tasty reward for these individuals because it has been attributed less incentive salience. For this reason, impulsive individuals without a high BAS trait are perhaps less likely to desire the largest portion sizes of this food.

Another important finding from this experiment which is worthy of consideration was that only impulsive individuals with high disinhibition scores were found to experience the greatest changes in desired portion size of the cued food when individuals were tested whilst satiated. This suggests that in the absence of hunger, impulsive individuals might also require a *specific* inability to resist the temptation to eat offered by external cues in order to desire larger portions of a food after being exposed to it briefly. This perhaps makes sense because it seems plausible that some bias towards food-related cues is essential to elicit an initial impulse to eat when individuals are satiated. Given that dietary disinhibition reflects a greater susceptibility to triggers in the environment which promote food intake, it seems that this dietary characteristic would constitute a bias towards food-related stimuli. For impulsive individuals, this initial bias is likely to prompt these individuals to make the rash decision to select a larger portion size of the cued food. However, in the absence of a tendency to act on impulse, individuals with high dietary disinhibition perhaps consider the consequences of selecting a larger portion size of their desired food, and thereby regulate the portion size that they select.

As an aside, whilst discussing the joint role of dietary disinhibition and impulsivity in food-cue reactivity, it is important to note that in this experiment, the greater change in desired pizza size experienced by individuals with simultaneously high impulsivity and

disinhibition scores did not result in the selection of the largest *total* portion sizes of this food after cue exposure. This is because they selected the smallest portion sizes of pizza prior to cue exposure, thus, their greater change in desired portion size was unable to stimulate the largest portion-size selection in the cued context. The reason these individuals selected the smallest portion sizes prior to cue exposure is likely to be because they had lower levels of hungry than the other groups prior to cue exposure. If, however, these individuals had had similar hunger levels at the outset, they would have been expected to select similar pre-exposure portion sizes, and as a result of their greater change in desired portion size they would have selected the largest portion sizes after cue exposure.

In addition to exploring associations between food-cue reactivity and impulsivity and sensitivity to reward, another aim of this experiment was to consider the extent to which associations between food-cue reactivity and 1) dietary restraint, and 11) being overweight differ when participants are deprived of food, relative to when they are non-food deprived. Previous experiments presented in this thesis have suggested that dietary restraint shares little relationship with food-cue reactivity when participants are tested immediately after lunch. The results from the present experiment confirm this finding and also suggest that restrained and unrestrained eaters do not differ in their reactivity when individuals are tested while food deprived. Therefore, taken together, this suggests that restrained eaters do not experience any greater reactivity to food cues than unrestrained eaters irrespective of whether they are food deprived or have recently eaten to satiety. This is perhaps not surprising given that relative to unrestrained eaters, restrained eaters would be expected to be exerting greater levels of restriction over their intake irrespective of their motivational state.

With regards to the associations observed between food-cue reactivity and being overweight, the findings were less expected. To recap, in Experiment 5, change in desired pizza size after cue exposure was found to be associated with being overweight whilst individuals were tested whilst satiated. However, in this experiment, not only was elevated reactivity not associated with being overweight when individuals were

food-deprived, but, contrary to the findings from Experiment 5, it was also not associated with food-cue reactivity when individuals were satiated. One difference in this experiment which might account for this is that overweight individuals were more restrained than the non-overweight individuals. Indeed, the mean restraint scores observed in this experiment for the overweight, and non-overweight, groups suggest that the overweight group in fact reflected a group of restrained eaters, whilst the non-overweight group reflected a group of unrestrained eaters. Thus, since comparisons were being made between restrained and unrestrained groups perhaps it is not surprising that there was little evidence of an association between food-cue reactivity and being overweight.

Another reason for the failure to report greater food-cue reactivity in overweight individuals might be because the sample of overweight participants recruited for this study did not have a higher BAS-related trait, or higher impulsivity scores, than non-overweight individuals. Indeed, the findings from this experiment have suggested that both these characteristics are important predictors of food-cue reactivity. Thus, following from this, one possibility is that the reason previous studies (e.g., Jansen *et al*, 2003; Tom & Rucker, 1975) have reported greater reactivity in overweight individuals is because they have recruited a group of overweight individuals with a high sensitivity to reward and high impulsivity. Indeed, previously, randomly selected groups of overweight have been found to score higher on these particular characteristics (Franken & Muis, 2005; Nederkoom *et al*, 2006; Nederkoom *et al*, in press). However, unfortunately, for the groups of overweight individuals previously found to experience greater cue reactivity there is no record of their levels of impulsivity or sensitivity to reward, making it impossible to explore this speculation. However, future studies might wish to consider this possibility further.

In light of the failure to report any overweight/non-overweight differences in food-cue reactivity in this study, little can be concluded regarding differences in food-cue reactivity in overweight, and non-overweight, individuals across different motivational states. This is disappointing because previous work suggests that such a difference

might in fact occur. For example, several studies have found that overweight individuals purchase greater amounts of food at a supermarket than non-overweight individuals when satiated, but that normal weight individuals in fact consume greater amounts as the time since previous meal increases (Mela, Aaron, & Gatenby, 1996, Nisbett & Kanouse, 1969; Tom, 1983). Since supermarket shopping exposes an individual to an array of food cues, these findings might therefore suggest that overweight individuals only experience greater reactivity to food cues than non-overweight individuals when satiated. Furthermore, another study conducted in the 1970's by Tom and Rucker (1975) suggested that overweight participants consumed larger amounts of food, and were willing to purchase more food, relative to non-overweight individuals, after exposure to food slides, but *only* when they had recently eaten to satiety. In fact, similar to the supermarket studies, after viewing the food slides while food-deprived, non-overweight individuals consumed greater amounts of food, and were willing to purchase modestly more of this food than overweight individuals. In light of this initial evidence in support of a difference in the extent to which overweight individuals experience greater food-cue reactivity than non-overweight individuals, future studies should explore this possibility further.

Finally, in this discussion it is important to address some of the limitations associated with the present experiment. One limitation is that in the first cue-exposure phase (i.e., food-deprived phase) the portion-size selections made using the food models in the non-cued context might have reflected modestly cued selections. The reason for suspecting this is because subjective appetite for these foods was found to increase after making these selections in this motivational state. This is problematic because if the changes were cued to some extent, then they might have been modestly conservative with respect to the actual change that would be stimulated by exposure to such a cue when hungry. A second limitation associated with this experiment was that the compliance check (i.e., food diary) administered to ensure that participants were in fact food deprived prior to the first cue exposure period was not optimal. A more appropriate check may have been to collect saliva samples which participants believed

would be analysed to determine that they had not ingested any food in the previous four hours.

A further potential limitation of this experiment was that despite attempts to minimise awareness of the aims of the study, a modest proportion of the participants did have some awareness that the experiment sought to investigate the effect of pizza-cue exposure on appetite ratings and desired portion size. However, post-hoc analyses did suggest that this awareness did not predict changes in these measures after cue exposure. Thus, even if some participants were aware of the aims of the experiment this did not appear to influence their responses throughout the experiment.

Finally, this experiment might be limited by the fact that two assessments of cue reactivity were made essentially within the same test session, i.e., one while participants were deprived of food, and one immediately after they had eaten to satiety. The most obvious implication of this is that by the second assessment participants were aware of the aims of the study. However, as suggested here, even if they were, this did not affect their subsequent reactivity. Another implication is that their responses in the second cue-reactivity assessment were affected by the fact that participants had already made these same assessments in the first phase of the experiment. This might explain why there were several outliers observed for the second set of reactivity measures. One possibility is that due to the large numbers of measures obtained in this experiment, participants became fatigued and began to make mistakes in the second set of measures. Another potential problem might have been that participants' assessments were influenced by those made previously. Particularly, this might have been the case for the measures of desired portion size. Evidence for this comes from the fact that in this experiment the mean change in pizza size observed after being cued with the pizza while satiated was much larger than that observed in Experiment 5. Therefore, one possibility is that these portion sizes were guided to some extent by the portions sizes made whilst participants were hungry. Thus, to assess the possibility that the results reported here might be an artifact of repeated testing, future studies should attempt to replicate these findings using a methodological design whereby cue exposure in the two

different motivational states is assessed in two separate test sessions. In these studies, participants should be randomised to a motivational state condition for the first set of testing sessions so that half the participants undertake the initial testing session while satiated and the other half while hungry.

7.6 Chapter summary

The experiment presented in this chapter explored associations between food-cue reactivity and i) dietary restraint, ii) dietary disinhibition, iii) body weight, iv) BAS activity and v) impulsivity, in two different motivational states (i.e., while individuals were food-deprived and in the absence of food deprivation). The results provided little evidence to suggest that food-cue reactivity was associated with individual differences in dietary restraint, or body weight in either of the motivational states. However, they did provide some evidence to suggest that impulsivity might be an important predictor of food-cue reactivity when food deprived and after recently eating to satiety. This trait was found to interact with disinhibition scores to predict greater changes in desired portion sizes of a cued food when individuals were satiated. Furthermore, in conjunction with a heightened sensitivity to reward, there was some evidence to suggest that impulsivity might also predict greater food-cue reactivity when individuals were hungry. Finally, sensitivity to reward (the BAS trait) was also found to be an independent predictor of changes in desired portion size of a cued food when individuals were satiated. Therefore, taken together, the findings from this experiment suggest that food-cue reactivity might be heightened in the most part due to the over-activity of a *universal* system which reacts to stimuli in the environment associated with rewards, and as a result of a general inability to resist impulses.

CHAPTER 8

GENERAL DISCUSSION

8.1 Chapter Introduction

The six experiments presented in this thesis have considered individual differences in food-cue reactivity. Importantly, several findings have emerged from these experiments that further our understanding of this dietary phenomenon. Specifically, the findings suggest that dietary restraint shares little association with food-cue reactivity, but that dietary disinhibition, impulsivity, and a greater sensitivity to reward (BAS trait) might be important predictors of this reactivity. In addition to this, potential links have also been highlighted between reactivity to food cues and everyday portion-size selections and being overweight. This chapter discusses these findings and considers their implications for food-cue reactivity, and for preventing, and reducing, overeating.

A secondary issue considered in this chapter is the limitations and methodological issues arising from the work presented in this thesis. These are discussed in the later sections of the chapter and future methodological innovations are proposed. The final section of this chapter considers the future for food-cue reactivity research, and proposes ideas relating to how research in this area can progress.

8.2 Food-cue reactivity and dietary restraint

Previously, it has been suggested that food-cue reactivity is associated with dietary restraint (e.g., Fedoroff *et al.*, 199, 2003; Rogers & Hill, 1989). However, given that the measure of restraint (i.e., the Restraint Scale) used in these studies does not provide a

pure measure of this dietary behaviour, this thesis began with an exploration of associations between food-cue reactivity and a purer measure of dietary restriction (i.e., the restraint scale from the DEBQ, van Strien *et al* , 1986). Using this purer measure, there was little evidence to suggest that food-cue reactivity shares a relationship with dietary-restraint status across six separate experiments. After food-cue exposure, restrained eaters did not experience greater subjective appetite for either the food which had been cued, or for the non-cued foods. In addition to this, they were not found to consume larger amounts of these foods (Experiments 1 and 2), or to desire larger portions of it (Experiments 3 to 6). Furthermore, this failure to observe greater cue reactivity in restrained eaters occurred when participants were tested while satiated and after four-hour food deprivation. Taken together, these findings suggest that dietary restraint does not place individuals at any greater risk of overeating in the presence of a food cue. This is important because it contrasts previous conclusions drawn from associations observed between the Restraint Scale and food-cue reactivity suggesting that restrained eaters overeat in the presence of food cues (e.g., Fedoroff *et al* , 1997, 2003, Rogers & Hill, 1989).

Finding that dietary restraint is not associated with food-cue reactivity is perhaps not surprising. This is because it is unclear why merely attempting to restrict one's dietary intake should result in an individual desiring larger amounts of a food which has been cued. Indeed, individuals who are attempting to inhibit a particular behaviour would not be expected to engage in that behaviour to a greater extent than those who are unconcerned with inhibition of that behaviour. Fenichel (1999) in his discussion of psychoanalytical theory explains why this is the case. He suggests that when tendencies to act in a particular way, and tendencies to inhibit that behaviour, are equally strong, there will be no motivated activity. Fenichel's (1999) explanation is important because it can in fact be used to provide an explanation of the behaviour of restrained eaters. Indeed, restrained eaters are likely to experience a motivation to eat in the presence of a food cue. However, their attempted restriction should counteract this motivation. Consistent with this, there is evidence to suggest that restrained eaters are motivated to eat after exposure to a food cue. For example, two separate studies have suggested that

restrained eaters (identified using pure measures of dietary restraint) experience greater salivary responses in the presence of a food cue (Brunstrom *et al* , 2004; Tepper, 1992). Yet, evidence from the experiments presented in this thesis also implies that restrained eaters are able to counteract this motivation because they do not indicate a desire to overeat a cued food. This successful inhibition might be the result of restrained eaters ability to actively avert their attention away from food cues (see Kemmotsu & Murphy, 2006; Piacentini, Schell, & Vanderweele, 1993).

Notably the idea that dietary restraint does not inadvertently cause greater reactivity to food is not consistent with all accounts of cued behaviour. For example, Tiffany (1990) suggests that inhibiting a particular behaviour can encourage initiation of this behaviour in the presence of enabling stimuli. Specifically, he suggested that inhibiting drug use can motivate further drug use in the presence of cues associated with this behaviour. However, the findings from the experiments presented here do not suggest that this is the case for food-cue reactivity. This is an important finding because it implies that the theoretical account of drug urges provided by Tiffany (1990) might not constitute an appropriate model for explaining food-cue reactivity.

Given that the findings presented here suggest that measures of pure dietary restriction fail to predict food-cue reactivity, it becomes important to ask what it is about the Restraint Scale (Herman & Polivy, 1980) that promotes associations with this dietary phenomenon. One possibility is that the Restraint Scale acts as a proxy measure for obesity-proneness (Lowe & Kral, 2006), and that it is this predisposition towards obesity which is associated with greater food-cue reactivity. However, an alternative possibility is that individuals who obtain high scores on the Restraint Scale oscillate between periods of intense calorie restriction and bouts of disinhibited eating (Lowe, 1993). Thus, put simply, rather than reflecting a measure of obesity proneness, the Restraint Scale might reflect the cyclic history of dietary restriction and excessive food intake (i.e., weight fluctuation) (Lowe, 1993). Given this, it is possible that weight cycling (e.g., Brownell, & Rodin, 1994, Foreyt, Brunner, Goodrick, Cutter, Brownell, & Stjeor, 1995, Kajioka, Tsuzuku, Shimokata, & Sato, 2002) accounts for associations

between the Restraint Scale and food-cue reactivity. An explanation for this potential association has been provided by Lowe (1993). He suggests that a single cycle of overeating, followed by a strict diet, will leave individuals at a greater risk for disinhibitory eating. This is because dieting has caused these individuals to become unresponsive to hunger cues, while the preceding overeating phase rendered these individuals insensitive to satiety cues. Consequently, these individuals are left to rely on external cues to guide their eating behaviour. Some support for this assertion comes from a study by Heatherton, Polivy, and Herman (1989). In this study, the authors gave participants a pill and told them that it had made a previous group of participants feel either more hungry, or feel more satiated. By doing this, Heatherton *et al.* (1989) found that individuals who obtained higher scores on the Restraint Scale (and thereby are assumed to be weight cycling) ate greater amounts when told that the pill made the previous group feel hungry, than when they were told that it made them feel more satiated. These findings were therefore taken to suggest that these individuals rely on external cues to guide their food intake. Thus, given this, it is possible that individuals who obtain high scores on the Restraint Scale also rely to a greater extent on external food cues to guide their intake, and in the absence of satiety signals, overeat in the presence of these cues.

Unfortunately, the extent to which food-cue reactivity shares an association with obesity-proneness, or weight cycling, was not considered in the experiments presented here. Rather, in this thesis it has been assumed that the Restraint Scale acts as a proxy measure for dietary disinhibition. This is because the Restraint Scale is known to conflate dietary restraint with disinhibited eating (Blanchard & Frost, 1983; Drewnowski *et al.*, 1982; Heatherton *et al.*, 1988; Johnson *et al.*, 1983; Laessle *et al.*, 1989; Lowe, 1984). For this reason, it was initially hypothesised that food-cue reactivity might in fact be more closely associated with the disinhibition subscale from the TFEQ (Stunkard & Messick, 1985). The following section discusses the findings from this thesis relevant to this hypothesis. It also considers related findings suggesting that impulsivity and sensitivity to reward are also important determinants of food-cue reactivity.

8.3 The role of dietary disinhibition, impulsivity, and sensitivity to reward, in food-cue reactivity

As suggested above, initially in this thesis it was hypothesised that dietary disinhibition might be an important predictor of food-cue reactivity. Thus, throughout the six experiments, associations between food-cue reactivity and dietary disinhibition were explored. However, across these experiments, support for this association was relatively weak. Although Experiments 1, 3, and 5 provided some support for such an association, Experiments 2 and 4 provided little evidence for this. However, interestingly, in the final experiment, this dietary behaviour was found to *interact* with impulsivity to predict greater food-cue reactivity when individuals were satiated. Thus, impulsive individuals with high levels of dietary disinhibition experienced the greatest change in desired portion size of pizza after brief exposure to this food. Given this, one possibility is that those experiments which previously reported associations between dietary disinhibition and food-cue reactivity did so because the disinhibited eaters in these studies were more likely to also have a high degree of impulsivity.

To understand the implications of an interaction between dietary disinhibition and impulsivity for food-cue reactivity, it is important to consider the impact of these separate traits on behaviour. With regards to impulsivity, it has been suggested that this trait reflects a blind obedience to internal drives, behaviour activated by an impulse, rather than by controlled and reasoned deliberation, or behaviour that is poorly conceived, prematurely expressed, unduly risky, or inappropriate to the situation (Evenden, 1999). Based upon this definition, and inspection of the items which comprise the EPQ-impulsivity scale, it appears that impulsivity reflects a general inability to *consciously* control one's behaviour. Thus, impulsive individuals might be described as failing to have the same levels of self control as less impulsive individuals. By contrast, dietary disinhibition perhaps reflects a more specific inability to exert control over one's food intake. Indeed, after inspection of the items that comprise the TFEQ-disinhibition scale, it has been suggested here that this dietary behaviour reflects an increased susceptibility to external triggers which promote food intake (see Section

4.5, Chapter 4).

Based upon these definitions of impulsivity and disinhibition, it appears that impulsive individuals with high levels of dietary disinhibition experience greater reactivity to food cues when satiated because they are highly susceptible to external triggers, such as food cues, and are also because they are more generally unable to execute sufficient self control over their behaviour. Thus, when faced with food cues these individuals are motivated to eat by the presence of this cue, and in the absence of sufficient self control, they experience the greatest change in desired portion size. The implication of this finding is that it suggests that when individuals are satiated, one potential cause of greater food intake after exposure to food cues might be a greater susceptibility to external triggers which promote food intake paired with a more general inability to control one's behaviour.

It is important to note that the findings from Experiment 6 did not provide any evidence of a statistically significant interaction between dietary disinhibition and impulsivity when participants were tested whilst hungry. However, in this motivational state, impulsivity was found to be a significant predictor of food-cue reactivity. This suggests that a greater susceptibility to external cues which promote intake (i.e., dietary disinhibition) might not be responsible for greater food-cue reactivity when individuals are mildly food deprived. Yet, in these circumstances an inability to generally maintain control over one's behaviour might continue to be an important predictor of this dietary phenomenon. It is important to note, however, that after controlling statistically for sensitivity to reward scores, impulsivity was no longer a significant predictor of greater reactivity to food cues whilst individuals were hungry. Exploration of this finding suggested that one possibility is that only impulsive individuals with a high sensitivity to reward experienced greater changes in desired portion size of the cued food. The reason for this is unclear and it might therefore be useful perhaps for attempts to be made to replicate this finding with larger sample sizes. Notwithstanding this, it is important to note that sensitivity to reward is most definitely an important predictor of food-cue reactivity. This is because when individuals were satiated this characteristic

was found to be associated with greater food-cue reactivity irrespective of individuals' levels of impulsivity

To recap, sensitivity to reward is mediated by the BAS (Behavioural Activation System). This is a hypothetical brain structure that responds to rewards or cues signalling reward by activating behaviour. In the previous chapter it was suggested that individuals with a higher BAS trait more readily approach environmental cues associated with a reward because they assign greater incentive salience to these cues (Pickering & Gray, 2001). The idea that assigning greater incentive value to an environmental cue might result in this cue eliciting an appetitive motivation is consistent with Berridge and Robinson's (1998) 'Incentive Salience' hypothesis. To recap, Berridge and Robinson (1998) suggest that environmental stimuli are assigned incentive salience after they have been associated with a reward. According to Berridge and Robinson (1998), as a result of this attribution these cues become capable of demanding attention and motivating behaviour towards acquiring the reward which they have become associated with. Importantly, consistent with the sentiment of Berridge and Robinson's (1998) theory, a number of other theories of motivated behaviour have also suggested that environmental stimuli come to elicit an appetitive motivation because they gain incentive motivation, or incentive value (e.g., Bindra, 1974, Bolles, 1972) (See section 1.4.3, Chapter 1). Thus, the findings from this thesis are also more generally consistent with these theories.

By suggesting that the Incentive Salience hypothesis can be used to describe food-cue reactivity, it implies that the mechanism which governs food-cue reactivity is in fact the same mechanism that governs other cued behaviours. This is because the Incentive Salience hypothesis can be regarded as a theoretical account for all motivated behaviours elicited by environmental cues. Indeed, sensitivity to drug cues is also assumed to result from the attribution of incentive salience to these cues. Robinson and Berridge (1993) in their 'Incentive Sensitization Theory' suggest that addictive drugs enhance the mesolimbic dopamine transmission responsible for the attribution of Incentive Salience, and consequently greater incentive salience is attributed to external

cues encountered immediately prior to drug use. Support for this theory comes from two recent studies which have suggested that reactivity to drug cues is associated with greater reactivity of the BAS (Kambouropoulos & Staiger, 2001, 2004).

The possibility that the same mechanism governs all cued behaviour is important because it suggests that individuals who have a highly reactive BAS are susceptible to all environmental stimuli which predict the receipt of a reward. However, it is important to note that these individuals are perhaps most vulnerable to greater sensitivity to food cues. This is because, for example, individuals must engage in drug use in order for drug-related cues to motivate further drug use. Thus, those individuals with a highly reactive BAS who never use drugs will not develop a greater sensitivity to drug cues. However, since eating is essential to sustain life, individuals cannot avoid this behaviour. Consequently, all individuals with a highly reactive BAS will unfortunately tend to develop a greater sensitivity to the stimulatory effects of food cues.

Thus, given that the BAS trait might be fundamental to food-cue reactivity, it is important to consider the mechanism which governs this system. Notably, individuals with a highly reactive BAS are assumed to attribute greater incentive salience to external stimuli. This attribution is guided by dopamine activation (Pickering & Gray, 2001). Given this, it would appear that a more reactive BAS is the result of greater dopamine activation. One possibility suggested by Pickering and Gray (2001) is that dopamine cells themselves might be more reactive to their incoming signals in high BAS, relative to low BAS trait, individuals. A high BAS trait would then be manifest as a more intense dopamine cell firing in response to positive reinforcers, or rewards. Consequently, external stimuli which predict these reinforcers would be attributed greater incentive salience on subsequent encounters. However, an alternative possibility is that BAS functioning might vary across individuals because of a variation in the number and/or functioning of dopamine receptors (Pickering & Gray, 2001). Findings from Wang, Volkow, Logan, Pappas, Wong, Zhu *et al.* (2001) suggest that the number of dopamine receptors might be lower in some individuals (i.e., overweight

individuals). These authors suggest that this deficit in dopamine receptors causes a 'reward deficiency syndrome.' As a consequence of this syndrome, individuals seek out rewards to counteract their deficiency. Consequently environmental stimuli that predict a reward might create a greater motivational state in these individuals

In addition to the mechanism by which individuals with a high BAS trait *attribute* greater incentive salience being unclear, it is also unclear *exactly* why this attribution stimulates a greater motivation to obtain the reward associated with that cue when it is presented on subsequent occasions. The Incentive Salience hypothesis suggests that this motivated behaviour occurs because once incentive salience has been attributed to a stimulus, this stimulus commands attention. This suggests that attribution of incentive salience to environmental cues by individuals with a highly reactive BAS leads to an attentional bias for these stimuli. Since an attentional bias, at least in part, is involuntary and unintentional, it is indeed likely that this bias provides an automatic pathway for greater motivation to obtain the rewards associated with these environmental cues.

There are at least two pieces of evidence consistent with the notion that cue reactivity more generally might be the result of an attentional bias caused by the attribution of greater incentive salience. Firstly, several studies have reported that drug users have an attentional bias for drug cues (e.g., Bradley, Mogg, Wright, & Field, 2003; Hogarth, Mogg, Bradley, Duka, & Dickinson, 2003; Mogg & Bradley, 2002; Munafo, Mogg, Roberts, Bradley, & Murphy, 2003), and that this is associated with a highly reactive BAS (Munafo, *et al*, 2003). Secondly, reports suggest that increasing levels of the neurotransmitter responsible for the attribution of incentive salience, i.e., dopamine, creates an attentional bias for drug cues (Franken, Hendriks, Stam, & Brink, 2004). Thus, taken together, it appears that reactivity to environmental cues predicting a reward might ultimately reflect the allocation of greater attention to these cues guided by incentive salience. However, at present, there is little formal evidence within the domain of food-cue reactivity to affirm that it is in fact this process which guides this dietary phenomenon. Only tentative support for this possibility can be taken from the

fact that the Restraint Scale, which is associated with food-cue reactivity (e.g., Fedoroff *et al.*, 1997, 2003), has also been associated with an attentional bias for food cues (Francis, Stewart, & Hounsell, 1997; Israeli & Stewart, 2001). Therefore, given this possibility that food-cue reactivity might result from a greater attentional bias, future research should address this further.

As an aside, it is important to acknowledge the fact that models other than Berridge and Robinson's (1998) Incentive Salience hypothesis have been proposed to explain cue reactivity. One particular alternative theory has been proposed by Tiffany (1990). Although this model was primarily devised to account for drug use, it is in fact applicable to other behaviours motivated by environmental cues, such as food intake. According to Tiffany (1990), drug use is controlled by habit. More specifically, he suggests that drug use is controlled by automatic action plans which require little conscious control. Thus, according to Tiffany (1990), when a smoker is cued by the sight of a cigarette packet, for example, he/she will automatically reach for the packet, take out a cigarette, light it, and begin to smoke it, without even realising that they have engaged in this behaviour.

Initially, it appears very difficult to reconcile Tiffany's (1990) account of cue reactivity with the Incentive Salience hypothesis adhered to here. However, one possibility is that these theories do not present competing accounts of cue reactivity. Rather, it may be that they account for different stages in the process by which environment cues come to motivate behaviour. During the early stages of learning, incentive learning might primarily control reactivity to cues. However, after this response has been learned and repeatedly performed, the behaviour might become automatically initiated by triggering stimuli, thus a habit is formed (Mogg, Field, & Bradley, 2005). Notably, Di Chiara (2000) has suggested that this process governs drug-cue reactivity. According to Di Chiara (2000) in the early stages of nicotine dependence, smoking behaviour is controlled by incentive learning processes. This is because, as a result of dopamine release, smoking-related cues acquire positive motivational properties. However, after extensive experience of smoking, incentive learning processes no longer play a primary

role in determining smoking behaviour, as there is a switch from incentive responding to a mode of habit-based responding. The findings from a study by Mogg *et al* (2005) provide some support for this model. In the rationale for this study, the authors suggested that if the Incentive Salience hypothesis only describes the initial stages of learning about the incentive properties of a drug cue, then predictions from this theory should only hold true in these initial stages. Consequently, Mogg *et al* (2005) hypothesised that only low levels of nicotine dependence should be associated with an attentional, and approach, bias for smoking cues. Consistent with this, the authors found that compared to moderate levels of nicotine dependence, low levels of nicotine dependence were associated with a bias towards approaching smoking-related cues, and an attentional bias for these cues. Consequently, these authors provided some support for the two-stage process of cue reactivity proposed by Di Chiara (2000).

Since food-cue reactivity shares many parallels with drug-cue reactivity one possibility is that the same two-stage model might also account for the initiation, and maintenance, of food-cue reactivity. Initially, individuals with a highly reactive BAS might select larger portions of food after they have been cued with this food because they have attributed greater incentive salience to food cues and thereby have an attentional bias for these cues. However, after repeatedly selecting these larger portion sizes in the presence of a food cue, this response might become an automatic behaviour elicited whenever this cue is encountered. Thus, rather than heightened BAS reactivity being associated with food-cue reactivity because incentive salience consistently governs food-cue reactivity, it might in fact be that those with the BAS trait *initially* assign greater incentive salience to food cues, and therefore, this trait is associated with greater food-cue reactivity. However, over time these individuals might in fact become habitually more cue reactive.

If, as suggested, reactivity to food cues does become an automatic process, this might explain why individuals with a more reactive BAS, experience greater changes in portion-size selection of a food after food-cue exposure, but do not report greater changes in subjective appetite. This is because, subjectively wanting a reward is likely

to be a non-automatic cognitive process. Indeed, Tiffany (1990) suggests that cravings and urges for cued objects require non-automatic cognitive processes. Furthermore, Kavangh, Andrade, and May (2005) in their 'Elaborated Intrusion theory (EI),' have suggested that for an individual to experience a conscious desire for an object which has been cued, they must cognitively elaborate on the thought of that object. In support of these theoretical proposals, several studies have confirmed the need for cognitive capacity in subjective appetite by suggesting that craving for an imagined food is reduced if participants are required to complete a concurrent task (Kemps, Tiggeman, & Hart, 2005, Kemps, Tiggeman, Woods, & Soekov, 2004; Steel, Kemps, Tiggeman, 2006). On the basis of this evidence it is possible that subjective appetite does in fact require non-automatic cognitive processing. Thus, if food-cue reactivity has become an automatic process in individuals with more reactive BAS's it follows that these individuals are unlikely to experience greater appetite for the cued food.

To summarise, this section has suggested that dietary disinhibition, impulsivity, and sensitivity to reward (BAS trait) might be important determinants of food-cue reactivity. These findings are important because they allow us to begin to understand the mechanisms which might govern reactivity to food cues. However, in addition to understanding these underlying mechanisms, it is also important to begin to understand the consequences of greater cue reactivity for overeating. Thus, the following section discusses findings from this thesis which suggest that food-cue reactivity might contribute to greater everyday food consumption and being overweight.

8.4 Potential consequences of greater food-cue reactivity for everyday food consumption and being overweight

One aim of this thesis was to consider the extent to which greater food-cue reactivity is associated with the consumption of larger everyday portion sizes and being overweight. Given that exposure to a food cue can increase *ad-lib* food intake (e.g., Cornell *et al*, 1989; Rogers & Hill, 1989), it follows that those individuals who are particularly

reactive to food cues might consume larger amounts of food within their everyday lives. This possibility was considered in Experiments 3 to 5 using a measure of everyday portion-size selection. The results from two of these experiments (Experiment 3 and 5) suggested that individuals who showed elevated sensitivity to food cues in the laboratory consumed larger amounts of food within their everyday lives. However, given the cross-sectional nature of these experiments, it is impossible to ascertain the extent to which susceptibility to food cues is directly responsible for the selection of larger everyday portion sizes. Yet, it is possible to conclude from these findings that greater food-cue reactivity might at least *maintain* overeating in highly responsive individuals

Notwithstanding the importance of these findings, it is useful to note that there are several limitations associated with the measure of everyday portion size used in these experiments. In particular, this measure comprised of an average indication of everyday portion sizes across only nine (Experiment 3), or 15 (Experiments 4 and 5), foods. Thus, this measure is likely to have provided only a very rough estimate of participants' everyday portion sizes. This is particularly true given that it will also have been influenced ultimately by liking for these foods. Furthermore, it is not even certain that recalled portion sizes of the nine to 15 foods were accurate recalls of the amounts that individuals would typically consume. This is because there is no evidence to suggest that portion-size estimations of everyday consumption made using the Food Atlas provide a valid indication of everyday portion-size selections. Evidence merely suggests that individuals are able to use pictures of food to indicate portion sizes of the food itself with modest accuracy (Lucas, Nitavong, Villemainot, Kaaks, & Clavel-Chapelon, 1995; Nelson, Atkinson, & Darbyshire, 1994; Venter, Macintyre, & Vorster, 2000). However, in the absence of evidence to suggest that participants are able to provide accurate assessments of *their* everyday portion size, this measure is in some respects limited. Its limitations are further increased by the fact that there is also reason to suspect that recall might be affected by the degree to which individuals are hungry when recalling these portion sizes. For example, Beasley *et al* (2004) found that everyday portion sizes were recalled as larger when individuals were hungry

relative to when they were satiated. Furthermore, here it was suggested in Experiment 4 that the inability to highlight an association between everyday portion size and food-cue reactivity might have been a result of the fact that in this experiment, unlike in Experiments 3 and 5, participants were asked to recall their everyday portion sizes prior to the buffet lunch while they were food deprived.

Given that the measure of everyday portion-size selections used in the experiments presented here might not in fact provide a valid indication of everyday consumption, it may be useful for future studies to devise a more valid test of everyday food consumption. Rather than assessing associations between reactivity to food cues and everyday portion size specifically, it might be more desirable to assess associations with daily calorie intake. This issue might be addressed by using validated measures such as the 24-hour dietary recall methods, or food record methods (see Buzzard, 1998 for a detailed account of these methods). Twenty-four hour recall methods are based upon an in-depth interview conducted by a trained dietary interviewer. This allows collection of specific information regarding consumed foods, preparation methods, recipe ingredients, and brand names. This information can then be analysed using computer software to provide a measure of daily Kcalorie intake. The food record measure also allows a measure of daily Kcalorie intake to be obtained, but uses a slightly different method. Specifically, this technique asks participants to keep their own record of their food intake over a 24-hour period. Using these methods, information regarding an individual's intake could be obtained over several days, and then compared with the level of food-cue reactivity observed in the laboratory. This research would be particularly important because evidence of greater daily intake in cue reactive individuals, after controlling for other relevant variables, would confirm the assumption that heightened reactivity to food cues presents a risk factor for overeating.

If, as assumed here, greater food-cue reactivity is a risk factor for overeating, one possibility is that susceptibility to food cues is also associated with being overweight. In Experiments 5 and 6, this possibility was explored. The findings from Experiment 5 suggested that overweight individuals experienced a greater change in desired portion

size of a cued food than non-overweight individuals. However, in Experiment 6 there was little evidence to suggest that measures of food-cue reactivity differed between overweight, and non-overweight, individuals. The reason for this inconsistency across the two studies is unclear. However, it is not unusual. In the 1970's, there were a series of studies which confirmed the association between sensitivity to food cues and being overweight (e.g., Nisbett, 1968a, Abramson & Stinson, 1977), and a separate groups of studies which failed to replicate these results (e.g., Rodin *et al.*, 1976; Rodin *et al.*, 1977).

The reason why *only* some groups of overweight individuals are found to experience greater sensitivity to food cues than non-overweight individuals is unclear. However, perhaps relevant to this, the group of overweight individuals who were *not* found to experience any greater reactivity to food cues than non-overweight individuals in this thesis (i.e., those in Experiment 6) were not found to be more impulsive, or to have a greater sensitivity to reward than the non-overweight group, but they were found to be more restrained. These might be important observations given that impulsivity, and sensitivity to reward, appear to be important determinants of food-cue reactivity (Experiment 6), and that dietary restraint could potentially suppress reactivity to food cues. Indeed, in light of these observations, one possibility is that greater impulsivity and a higher sensitivity to reward can render *some* overweight individuals more susceptible to food cues than non-overweight individuals. Thus, this might explain why the overweight group in Experiment 5 were found to be more cue reactive than non-overweight individuals. However, unfortunately, in Experiment 5 levels of impulsivity and sensitivity to reward were not measured making it impossible to ascertain the extent to which this is in fact the case.

Finding that greater food-cue reactivity is not consistently observed in overweight individuals is perhaps not surprising. This is because, firstly, obesity is a multifaceted disease with a magnitude of potential causal factors including such things as a genetic predisposition (for a review see Loos, & Bouchard, 2003), greater snack consumption (e.g., Francis & Birch, 2003), and more frequent fast food consumption (e.g., Pereira,

Kartashov, Ebbeling, Van Horn, Slattery, Jacobs *et al* , 2005) etc.. Thus, it is extremely unlikely that all individuals who are overweight became overweight because they are more sensitive to the effects of food-cue exposure on appetite. The second reason for not consistently observing greater food-cue reactivity in overweight individuals is because some individuals who became overweight because they were more reactive to food cues might now be using dietary restriction to inhibit this heightened reactivity. Thus, greater food-cue reactivity may no longer be observed in these individuals.

Thus, although food-cue reactivity might cause weight gain, this does not necessarily mean that an association will be found between being overweight and food-cue reactivity. This is because not all overweight individuals will experience a greater sensitivity to food cues. Some may have become overweight for reasons other than being more susceptible to food cues, and some might now be attempting to inhibit their reactivity by consciously restricting their dietary intake. Thus, given this, to successfully investigate the role of food-cue reactivity in weight gain, future studies might seek to adopt a longitudinal approach. Specifically, reactive and non-reactive individuals could be identified and their weight gain monitored over several months. This work would be particularly important because it would further enhance our understanding of obesity, and inform the design of interventions aimed to reduce, or prevent, overeating. The work presented here provides a first step towards doing this. However, future work is required to further investigate this issue.

8.5 Implications of this research for interventions designed to reduce obesity

In light of the recent increases in obesity, it is desirable to identify interventions which might reduce body weight in overweight individuals. Although the extent to which food-cue reactivity promotes weight gain is not entirely clear from the experiments presented in this thesis, it is likely to present one causal factor. Thus, given this, it might be important to reduce heightened reactivity to food cues. In Chapter 6 it was suggested that one method to achieve this might be to prevent individuals from eating

in the presence of food cues (Response Prevention) This technique was originally proposed by Jansen (1998). Jansen (1998) suggests that overeating in the presence of a food cue becomes associated with cues encountered immediately prior to this act. Thus, when these environmental cues are subsequently encountered they motivate overeating. Although the result from the experiments presented in this thesis provide a rather different theoretical accounts of the process by which food cues come to motivate eating behaviour (see Section 8.3), a response prevention technique might still be important for reducing elevated food-cue reactivity. This is because it has been suggested that food-cue reactivity eventually reflects a habit to overeat in the presence of food cues (see Section 8.3). Thus, this technique would serve to break this habit.

Notwithstanding the fact that this response-prevention technique is attractive, the feasibility of it might in fact be compromised. Essentially, this is because individuals must eat to sustain life. Thus, even if established cued responses can be extinguished, new cued responses will be immediately re-established as individuals continue to eat in the presence of environmental stimuli. This will occur because these individuals will re-attribute greater incentive salience to these stimuli. The reason a Response Prevention technique is able to extinguish drug-cued responses after administration of the treatment is because patients no longer have any reason to use drugs. Yet, after administering this treatment to reduce food-cue reactivity, individuals would still be required to eat to sustain life. Thus, as a consequence of this, cued responses would be re-established. In light of this inefficiency of the Response Prevention method to permanently eliminate over-reactivity to food cues, other techniques need to be established. Given that attribution of incentive salience to food cues and a lack of inhibitory control are likely to be responsible for continued reactivity to food cues after the administration of a Response Prevention technique, it is perhaps these behaviours which require treatment to permanently inhibit food-cue reactivity. However, since it would be extremely difficult to intervene in the attribution of incentive salience because this is guided by dopamine activation, it might be more feasible to attempt to train individuals to inhibit their tendency to overeat in the presence of a food cue. This might be achieved by teaching individuals to consciously control the amounts of food that

they eat after food-cue exposure. However, it is important to note that the feasibility of this intervention is not known and for this reason future studies might seek to consider this further.

8.6 Limitations and methodological considerations

The preceding sections have sought to discuss the findings from the experiments presented in this thesis. Notwithstanding these findings, it is important to note that there were several limitations associated with the experiments presented here. Some of these limitations were addressed as the thesis progressed. However, there are several limitations which remain unresolved. This section provides a chronological account of the methodological approaches adopted in the experiments presented here, their limitations, and where applicable how these methods were improved upon. This begins by considering the methodologies employed in the initial experiments.

In the early experiments (i.e., Experiments 1 and 2) the methodological design followed those typically used in previous studies exploring food-cue reactivity. Consequently, a between-subjects design was employed. Participants were randomly assigned to a no-cue, or a pizza-cue, condition. The effect of cue exposure on appetite ratings and *ad-lib* intake was then compared across the two conditions. The reason this approach has been used in experiments exploring food-cue reactivity is likely to be because it reduces demand awareness. Indeed, if participants had participated in two identical test sessions which only differed in the extent to which they were cued with pizza, they would almost certainly have deduced the aims of the study. Consequently, it is likely that the participants would have felt inclined to behave in the way they felt they were expected to by the researcher. For these reasons, this between-subjects approach appears advantageous. However, it is not without limitations. For example, it is less powerful than a within-subjects design. This is because the same participant cannot be compared across the two conditions.

In later experiments presented in this thesis (Experiments 4-6), a within-subject methodology was employed. Thus, rather than some participants providing cued measures and others providing non-cued measures, each participant provided both measures within a single test session. The measure taken in the non-cued context was then treated as a baseline measure, or a pre-exposure measure, and the cued measure served as a post-exposure measure. This allowed the difference (change score) between these two measures to be calculated and thereby the effect of cue exposure could be assessed. This approach was advantageous because it was more powerful than a between-subjects design. This is because it allowed comparisons between the effects of food-cue exposure on appetite to be made within each participant. However, this approach does introduce a greater risk of participants becoming aware of the experimental aim. An attempt was made to assess this awareness by issuing an awareness questionnaire in the final stages of the experiments. These questionnaires provided evidence to suggest that a proportion of the participants were aware of the experiments interest in the effects of food-cue exposure on appetite ratings and food intake. However, importantly, post-hoc analysis suggested that this did not promote greater food-cue reactivity and did not vary across the predictor variables (i.e., dietary restraint, dietary disinhibition, everyday portion sizes, being overweight, impulsivity, and BAS trait). Nevertheless, it is impossible to entirely eliminate the possibility that demand awareness played some role in the responses that were observed. This is because, firstly, it is possible that the questions designed to assess the study aims lacked sensitivity to detect awareness in all individuals. Secondly, some participants may have been aware of the experiments aims but did not articulate this well in their responses to the questions.

Typically, when utilising a within-subjects design such as that employed in the later experiments, conditions should be randomised to avoid order effects. This is because fatigue factors might contribute to performance in later conditions, and novelty factors might be implicated in performance in earlier conditions. However, it was impossible to randomise the order in which participants completed the no-cue, and pizza-cue, conditions in the experiments presented here. This is because this would elicit a greater

awareness of the study aims in those individuals who initially completed the pizza-cue condition. Furthermore, to randomise the order of the conditions, the study would have had to be run over two separate sessions. This is because the pizza-cue condition could not precede the no-cue condition in a single test session. However, this approach is problematic because it is impossible to ensure that participants are in identical motivational states prior to cue exposure in the two separate sessions. For example, it would be impossible to ascertain whether an individual was satiated or hungry to the same extent prior to cue exposure in each of the test sessions.

In food-cue reactivity studies, it is essential to obtain measures of cue reactivity in the absence of food-cue exposure. This is because by doing this the exact effect of cue exposure on appetite can be established. However, as suggested earlier in this thesis (see Section 3.9, Chapter 3), obtaining a measure of food intake in a non-cued context is particularly difficult. This is because even very brief exposure to a food cue is likely to act as a cue. In the original methodology employed in this thesis (e.g., Experiments 1 and 2), participants in the no-cue condition were presented with pizza in the *ad-lib* intake phase. However, it was suspected that the sight, smell, and taste, of the test food in this phase cued participants' appetite for this food, thereby creating another cued condition. In light of this, in subsequent experiments it was decided that a measure of desired portion size using food models which reflected only the very basic elements of the food would be used to assess reactivity in a non-cued context. To ensure the suitability of this approach, appetite ratings were taken before and after participants had indicated their desired portion size using the food models. These ratings suggested that the models had little effect on subjective appetite when participants were tested immediately after eating to satiety. However, in Experiment 6, there was some evidence to suggest that these models were able to cue appetite for the foods they represented when participants had been deprived of food for four hours. This finding is important because it suggests that food models might not in fact provide a non-cued measure of food-cue reactivity when individuals are hungry. For this reason, the findings from Experiment 6 must be interpreted in light of this.

The fact that food models might reflect cued measures in some circumstances is not the only limitation associated with the use of these models. Another limitation is that these models provide very little information about the food they represent. Thus, as a consequence of this, participants are required to draw upon other resources to indicate their desired portion size. This is problematic because these resources will differ from participant to participant. The most unrepresentative food model used in the experiments presented here was pizza. This is because it was rectangular in shape rather than circular. As a consequence of this, participants almost certainly had to rely to some extent on their imagination of what this pizza might be like to indicate their desired portion size. Thus, this introduces a bias into this measure as different participants will have been imagining different pizzas. For this reason, it might be useful to replicate the findings presented here using more descriptive food models. This would ensure that all participants are using the same information in order to indicate their desired portion sizes.

A further limitation of the pizza model was that it did not allow the participants to see the actual three-dimensional size of pizza that they were selecting. To recap, for the pizza-size selections participants were provided with a three-dimensional model of pizza which was identical in size to the slice of pizza they were exposed to in the exposure phase. They then made their portion size selections on a one-dimensional sheet of card. As a consequence of this, they had to imagine how the one-dimensional slice that they selected would look if it was a three-dimensional pizza. Again, this introduces some aspect of error into this measure. Therefore, in retrospect, a less biased measure of desired pizza slice might have been obtained by providing a very large three-dimensional pizza and asking participants to indicate their desired portion size using this model.

In light of the limitations associated with obtaining direct measures of intake after food-cue exposure perhaps it might be useful for future studies to consider other methods by which to assess likely food intake after food-cue exposure. One approach might be to rely solely on appetite ratings to assess reactivity to food cues. However, this is not

advisable because these measures assess subjective appetite and cannot be relied upon as providing a reliable measure of potential intake. For example, Mattes (1990) reported discrepancies between hunger ratings and reported intake in a 7-day study. Furthermore, after a comprehensive review of the literature, Stubbs, Hughes, Johnstone, Rowley, Reid, Elia *et al* (2000) concluded that although visual analogue scales correlate with energy intake, they do not reliably predict energy intake to the extent that they could be used as a proxy for this. Given this, an alternative option might be to assess the likelihood of participants *initiating* intake after food-cue exposure. In other words, identifying those individuals, who after food-cue exposure, actively decide to obtain the cued food. Besides providing an alternative to the potentially flawed behavioural measures used in the experiments presented here, this approach would in fact provide a more reliable assessment of those individuals who are most likely to engage in food intake after exposure to a food intake. This is because, outside the context of the laboratory, individuals will be exposed to food cues, such as the sight of food, and then will either continue their normal activity or will actively decide to obtain that food. Thus, perhaps it is not important to assess the portion size that individuals select after food-cue exposure, but rather the likelihood that this exposure motivates individuals to obtain and consume the cued food. Indeed, in many circumstances, after being exposed to a food cue individuals perhaps do not have a choice over the portion size they select. This might be because the food which has been cued happens to only be available in a pre-determined size. For example, if individuals are cued by a poster advertisement depicting a McDonalds Big Mac those individuals who are highly sensitive to this cue and would therefore like to consume this food would have almost no choice over the portion size of food which they eat. This is because the portion sizes of these varieties of food are pre-determined by the fast food establishments. Thus, on the basis of this discussion, future studies might wish to devise a measure to assess the likelihood that a cued food will be actively obtained. Tom & Rucker (1985) used one approach which was designed to do this. After briefly exposing participants to a food cue, these authors asked them to indicate whether they would like to consume crackers. However, the specific approach used in this study was flawed by the fact that the food offered for consumption was not that which had been

cued Future studies might therefore wish to adopt an approach similar to that used by Tom & Rucker, but should improve upon this methodology by enquiring about future consumption of the cued food.

Apart from these specific limitations associated with the design of the experiments presented here, there are several other more general limitations. Firstly, each study tested a cohort of female students aged between 18 and 30 The decision to recruit from this specific population was motivated entirely by the fact that in recent studies exploring food-cue reactivity participants have been recruited from this specific population. Thus, it was useful to adhere to recruiting from this population to ensure that the findings obtained for the experiments were easily comparable to those of previous studies However, despite this, this strategy is not without limitations. Indeed, as a result of this decision, the sample constituted a group of individuals who were of a particular gender, came from a narrowly defined age group, were of a particular educational level, and most likely were over-representative of a particular social class. Thus, the findings from the experiments presented here cannot be used to describe the behaviour of the population as a whole. Rather, the conclusions formulated as a result of the findings can only be confidently used to describe the behaviour of the subsection of the population which the sample is recruited from.

Secondly, the same cued food was used in the most part throughout the six experiments. The decision to use pizza as the cued food was motivated by the fact that it is a popular fast food and that it is foods such as these which are likely to be having a sufficient impact on the obesity epidemic. In addition to this, this food has been used in previous studies exploring food-cue reactivity (e.g., Fedoroff *et al* , 1997, 2003). Therefore, again, to ensure that the findings from the experiments presented here could be easily compared with previous studies, it was desirable to use pizza as the cued food. However, it might be useful for future studies to replicate the findings from the experiments presented here using different foods. This would ensure that the findings reported here are not specific to pizza

A third more general limitation of the work conducted here is that some of the experiments presented within it might not comprise sample sizes sufficient to use regression analyses incorporating the number of predictor variables and controlling variables that were used. For example, in both Experiment 3 and Experiment 4, 30 participants were recruited. The decision to use samples of this size was motivated by the sample sizes used in previous cue reactivity studies. For example, in a study comprising three conditions, Fedoroff *et al* (1997) used a sample size of approximately 90 participants. Thus, in experiments such as Experiments 3 and 4, which comprised essentially only one condition, it was decided that a sufficient sample would comprise 30 participants. However, according to Field (2005), with the three predictors used in these experiments and the two controlling variables, to achieve 80% power, using regression analysis a sample size of approximately 50 participants would be required. Thus, in retrospect, larger sample sizes should have been used in these experiments.

The fourth limitation of this thesis is that an identical cue reactivity paradigm was employed in each study. As a consequence of this, in each of the six experiments participants were exposed to the food cues for three minutes. However, it might be useful to assess individual differences in food-cue reactivity when individuals are exposed to a food cue for a much shorter period of time. This is because, outside the context of the laboratory, participants might be exposed to a food cue for only a matter of seconds. Therefore, it might be useful to determine the effects of cue exposure in these circumstances.

The final limitations of the research presented here relate to the *ad-lib* lunch used in each experiment, and the failure to acknowledge human variation in smell. With regards to the *ad-lib* lunch, one possibility is that this lunch served to cue participants appetite and this in some way affected the later changes that were observed in their cue reactivity. In an attempt to address this issue, the methodology applied in each experiment aimed to isolate the effects of cue exposure on appetite by exploring participants change in motivation to eat from immediately before, to immediately after, cue exposure. However, despite this, it remains possible that the *ad-lib* lunch cued

participants appetite and this in some way impacted on their later reactivity to the cued food (i.e., pizza or chips). A further limitation associated with the *ad-lib* lunch was that participants intake in this phase of the experiment was not measured. This is problematic because *intake* at this lunch may also have affected participants' reactivity in the later cue exposure phase. Given this, in retrospect, intake in this phase should have been measured for each participant and entered as a covariate into the analyses of cue reactivity. In addition to failing to acknowledge the potential effect of the *ad-lib* lunch on food-cue reactivity, this research also failed to address the possibility that individual variation in sense of smell might predict food-cue reactivity when olfactory stimuli are used as a cue. To address this limitation, future studies might attempt to implement a measure of sense of smell and also include this as a covariate in any analyses of cue reactivity.

In summary, there are several limitations associated with the experiments presented in this thesis. These relate to the experimental design, the measures that were employed, the materials used, and also the sample selection. Given these limitations, it would be desirable for future studies to replicate the findings presented here using improved methodological designs which consider these limitations.

8.7 Directions for future research

Following from the research presented in this thesis, there are two main areas which future studies might wish to pursue. Firstly, it is important to determine the exact effect of food-cue exposure on daily Kcalorie intake, and to explore the extent to which those individuals who are particularly cue reactive are at a greater risk of developing obesity. This area of research is particularly worthy of consideration given that it might further enhance our understanding of obesity. To address this issue, future studies might consider using 24-hr recall, and food record, methods to assess associations between food-cue reactivity and daily intake (see Section 8.4), and by using longitudinal methods to monitor any weight gain in cue reactive, and non-cue reactive, individuals.

The second series of questions which require further attention following from the research presented in this thesis are those related to the potential roles of sensitivity to reward and impulsivity in food-cue reactivity. The findings from the experiments presented here suggest that elevated food-cue reactivity might result from attributing greater incentive salience to foods. Given this, a first task for future research might be to further substantiate the role of incentive salience in the initiation of food-cue reactivity by addressing some of the limitations associated with the experiments conducted here. After this, it might also be desirable to test the extent to which the attribution of greater incentive salience transforms food cues into stimuli capable of demanding attention. This particular question warrants scrutiny because it has been suggested that the attribution of incentive salience transforms food cues into attractive, and attention grabbing, stimuli. To address this issue, attentional biases for food cues could be explored in the same way that attentional biases are assessed for drug cues, i.e., using techniques such as the adapted versions of the Stroop task. The Stroop effect (Stroop, 1935) is demonstrated by asking participants to name the colour in which colour words (e.g., red) are printed. Typically, individuals attend to the word itself and therefore find it very difficult to simply name the colour the word is printed in. In the literature on dietary control, there have been several studies which have adapted this task to explore attentional biases for food words (e.g., Braet & Combez, 2003; Lattimore, Thompson, & Halford, 2000). However, there have been no attempts to explore the associations between food-cue reactivity and attentional bias for food cues. Thus, it is important to now use these tasks to address this issue.

Another avenue for future research might involve determining the extent to which, over time, food-cue reactivity does indeed become an automatic process governed by automatic action plans and is therefore exempt from cognitive control. It is important to address this issue because it has been suggested that, over time, cued responses might become habitual and controlled by automatic action plans (see section 8.3). To address this issue, performance on a cognitive task could be assessed in both a cued, and a non-cued, context. If performance is not impaired in the cued context, but reactivity to the

food cue is observed, it can be concluded that food-cue reactivity requires little cognitive resource and is therefore controlled by automatic action plans. The reason for this is that if food-cue reactivity requires cognitive processing, performance on a task whilst being cued with food would be expected to be impaired because fewer cognitive resources would be available for the task. Similar approaches have been used previously to determine the extent to which attempts to restrict one's dietary intake in the presence of a food cue consumes cognitive resource (e.g., Brunstrom *et al.*, 2004, Green *et al.*, 1999; see section 3.5, Chapter 3). Such approaches are based on a single-capacity model of cognitive resource. This model suggests that there is a limit on cognitive capacity (Kahneman, 1973). Thus, once all cognitive resource has been allocated, performance on a second task is impaired (dual-task methodology).

In addition to testing the three hypotheses outlined above it might also be desirable for future research to provide further evidence for the role of impulsivity in food-cue reactivity. One way in which future studies might do this is by experimentally manipulating impulsivity. For example, one group of individuals might be trained to feel more impulsive, than a second untrained group. This might be an important study because it would confirm the causal role of this characteristic in this dietary phenomenon. A similar procedure has already been employed in a more general study assessing the role of impulsivity in overeating (e.g., Guerrieri, Nederkoorn, & Jansen, 2006).

8.8 Final remarks and conclusions

Previous studies have suggested that brief exposure to food-related stimuli, such as the sight and smell of food, can stimulate food intake (e.g., Fedoroff *et al.*, 1997, Nederkoorn *et al.*, 2004). However, despite this basic research, very few studies have sought to identify those individuals who are particularly reactive to food cues, or to explore the potential implications of this phenomenon for everyday dietary intake, and for being overweight. In light of this, the research presented in this thesis sought to

explore this issue. Specifically, it considered associations between food-cue reactivity and everyday dietary behaviour (dietary restraint and disinhibition), everyday portion-size selections, being overweight, and personality characteristics, such as impulsivity and sensitivity to reward. Importantly, by doing this, this thesis has advanced current understanding of food-cue reactivity in two main ways. Firstly, it has suggested that restricting ones dietary intake does not render an individual more susceptible to the effects of food-cue exposure. Rather, it has identified the importance of characteristics such as sensitivity to reward (i.e., BAS trait), impulsivity, and dietary disinhibition, for food-cue reactivity. Specifically, it has suggested that those individuals who possess these particular characteristics are likely to be more sensitive to the effects of food-cue exposure. Acknowledging the role of these characteristics is important because it implies that food-cue reactivity can result from the attribution of greater incentive value to food cues, and from a general inability to inhibit responses when a reward is imminent, or when a susceptibility towards external triggers which promote food intake exists (i.e., dietary disinhibition). The second way in which the research presented in this thesis has advanced understanding of food-cue reactivity is by identifying potential links between this dietary phenomenon and everyday food consumption and being overweight. Specifically, this thesis suggests that food-cue reactivity might present one factor which contributes to overeating, and weight gain. To move forward within this research area, studies should continue to investigate the role of food-cue reactivity in overeating, and should seek to further identify the mechanisms which promote greater reactivity to food cues in an attempt to design interventions to alleviate the current obesity epidemic.

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APPENDIX A

The following questions involve rating scales. On each scale please mark a vertical line to indicate your response to the question and please ensure that you use the full range of the scale.

How **HUNGRY** do you feel **RIGHT NOW**?

NOT AT
ALL HUNGRY |-----| EXTREMELY
HUNGRY

How **FULL** do you feel **RIGHT NOW**?

NOT AT
ALL FULL |-----| EXTREMELY
FULL

How **STRONG** is your desire to eat pizza/chips/cookies **RIGHT NOW**?

NOT AT
ALL STRONG |-----| EXTREMELY
STRONG

How much do you **CRAVE** pizza/chips/cookies right now **RIGHT NOW**?

NOT AT ALL

VERY MUCH

APPENDIX B

The restraint scale from The Dutch Eating Behaviour Questionnaire (DEBQ, van Strien *et al* , 1986)

When you have put on weight do you eat less than you usually do?	not relevant	never	seldom	sometimes	often	very often
Do you try to eat less at mealtimes than you would like to eat?		never	seldom	sometimes	often	very often
How often do you refuse food or drink offered to you because you are concerned about your weight?		never	seldom	sometimes	often	very often
Do you watch exactly what you eat?		never	seldom	sometimes	often	very often
Do you deliberately eat foods that are slimming?		never	seldom	sometimes	often	very often
When you have eaten too much, do you eat less than usual the following day?	not relevant	never	seldom	sometimes	often	very often
Do you deliberately eat less in order not to become heavier?		never	seldom	sometimes	often	very often
How often do you try not to eat between meals because you are watching your weight?		never	seldom	sometimes	often	very often
How often in the evenings do you try not to eat because you are watching your weight?		never	seldom	sometimes	often	very often
Do you take your weight into account with what you eat?		never	seldom	sometimes	often	very often

APPENDIX C

The disinhibition scale from the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985).

1 When I smell a sizzling steak or see a juicy piece of meat, I find it very difficult to keep from eating, even if I have just finished a meal **True False**

2 I usually eat too much at social occasions, like parties and picnics **True False**

3 Sometimes things just taste so good that I keep on eating even when I am no longer hungry **True False**

4. When I feel anxious I find myself eating **True False**

5. Since my weight goes up and down I have gone on reducing diets more than once **True False**

6 When I am with someone who is overeating I usually overeat too **True False**

7. Sometimes when I start eating, I just can't seem to stop **True False**

8. It is not difficult for me to leave something on my plate **True False**

9. When I feel blue I often overeat **True False**

10 My weight has hardly changed at all in the last ten years **True False**

11. When I feel lonely, I console myself by eating **True False**

12 Without even thinking about it, I take a long time to eat **True False**

13 While on a diet, if I eat a food that is not allowed I often then splurge and eat other high calorie foods **True False**

14 Do you eat sensibly in front of others and spurge alone?

1.	2	3	4
Never	Rarely	Often	Always

15 Do you go on eating binges though you are not hungry?

1	2	3.	4
---	---	----	---

Never	Rarely	Sometimes	At least once a week
16 To what extent does this statement describe your eating behavior? - "I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising myself to start dieting again tomorrow."			
1 Not like me	2 Little like me	3 Pretty good description of me	4 Describes me perfectly

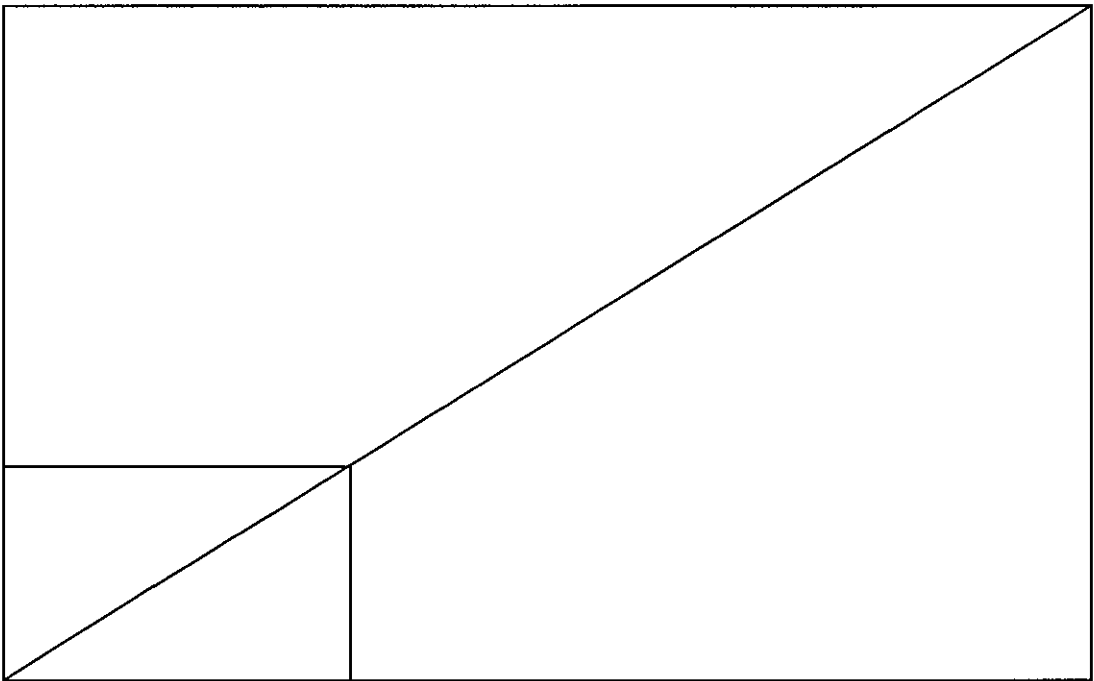
NB For items 1–7, 9, 11, and 13 a score of 1 is given for a ‘true’ response and zero for a ‘false’ response.

For items 8, 10, and 12 a score 1 is given for a ‘false’ response, and 1 for a ‘true’ response.

For items 14, 15, and 16 options 1 and 2 score zero points and options 3 and 4 score 1 point.

APPENDIX D

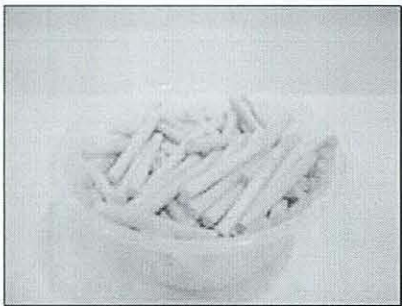
A picture of the card that participants used to indicate their desired portion size of pizza. An example of a portion size which a participant might select is indicated.



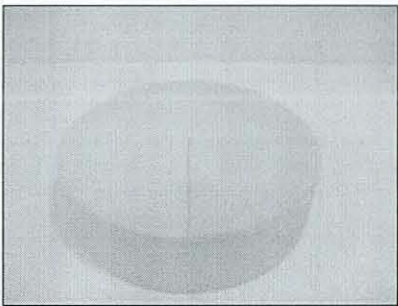
APPENDIX E

Pictures of the food models used in Experiments 4 to 6.

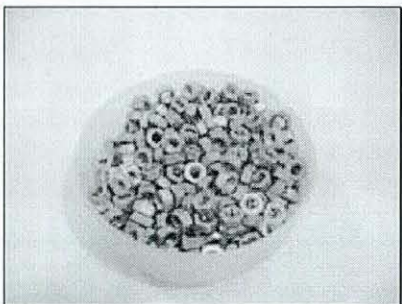
Chips



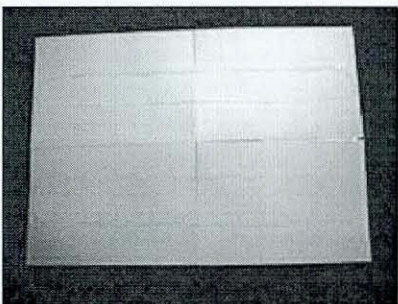
Chocolate cake



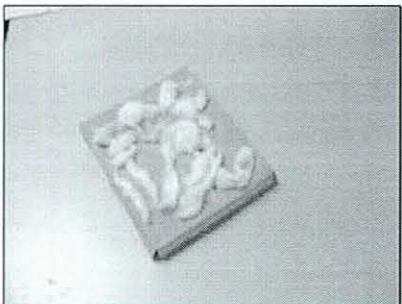
Peanuts



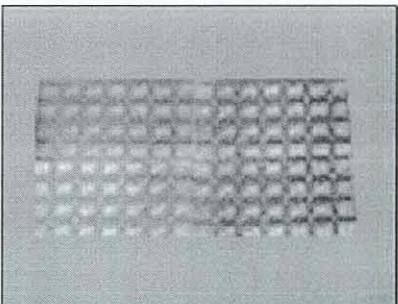
Garlic bread



Pizza



Chocolate



APPENDIX F

Health screening questionnaire

1 Age

2 Height

3 Weight

4 Do you smoke?

5 If so, how many cigarettes do you smoke a week?

6 Approximately, how many units of alcohol do you drink each week (a pint of average strength beer is 2 units, a 125ml of wine is 1 unit, 25ml of spirits is 1 unit)?

7 How often do you engage in physical activity each week and what type of activities do you engage in?

8 Are you currently taking any medication?

APPENDIX G

The Sensitivity to Reward scale (SR) from the Sensitivity to Reward and Sensitivity to Punishment Questionnaire (SRSPQ; Torrubia, *et al* , 2001)

- 1 Does the good prospect of obtaining money motivate you strongly to do some things? Y N
- 2 Are you frequently encouraged to act by the possibility of being valued in your work, in your studies, with new friends or with family? Y N
- 3 Do you often meet people that you find physically attractive? Y N
- 4 Do you like to take some drugs because of the pleasure you get from them? Y N
- 5 Do you often do things to be praised? Y N
- 6 Do you like being the centre of attention at a party or a social meeting? Y N
- 7 Do you spend a lot of your time on obtaining a good image? Y N
- 8 Do you need people to show their affection for you all the time? Y N
9. When you are in a group, do you try to make your opinions the most intelligent or the funniest? Y N
- 10 Do you often take the opportunity to pick up people you find attractive? Y N
- 11 As a child did you do a lot of things to get peoples approval? Y N
- 12 Does the possibility of social advancement, move you to action, even if it involves not playing fair? Y N
- 13 Do you generally give preference to those activities that imply an immediate gain? Y N
- 14 Do you often have trouble resisting the temptation of doing forbidden things? Y N
15. Do you like to compete and do everything you can to win? Y N
- 16 Is it easy for you to associate tastes and smells to pleasant events? Y N
- 17 Are there a large number of objects or sensations that remind you of pleasant events? Y N
18. When you start to play with a slot machine is it often difficult for you to stop?
Y N
- 19 Do you sometimes do things for quick gains? Y N
- 20 Does your attention easily stray from your work in the presence of an attractive stranger?
Y N
- 21 Are you interested in money to the point of being able to do risky jobs? Y N
- 22 Do you like to put competitive ingredients in all your activities? Y N

23 Would you like to be a socially powerful person? Y N

24 Do you like displaying your physical abilities even though this may involve danger? Y N

APPENDIX H

The impulsivity Questionnaire from Eysenck's Personality Questionnaire (EPQ, Eysenck & Eysenck, 1975)

- | | |
|---|-----|
| 1 Do you often buy things on impulse? | Y N |
| 2 Do you generally do and say things without stopping to think? | Y N |
| 3 Do you often get in a jam because you do things without thinking? | Y N |
| 4 Are you an impulsive person? | Y N |
| 5 Do you usually think carefully before doing anything? | Y N |
| 6 Do you often do things on the spur of the moment? | Y N |
| 7 Do you mostly speak without thinking things out? | Y N |
| 8 Do you often get involved in things you later wish you could get out of it | Y N |
| 9 Do you often get 'carried away' by new and exciting ideas, that you never think if possible
snags? | Y N |
| 10 Do you need to use a lot of self-control to keep out of trouble? | Y N |
| 11 Would you agree that almost everything enjoyable is illegal or immoral? | Y N |
| 12 Are you often surprised at peoples reactions to what you do or say? | Y N |
| 13 Do you think an evening out is more successful if it is unplanned or arranged at the last
moment? | Y N |
| 14 Do you usually work quickly, without bothering to check? | Y N |
| 15 Do you often change your interests? | Y N |
| 16 Before making your mind up, do you consider all the advantages and disadvantages? | Y N |
| 17 Do you usually like to 'sleep on it' before making decisions? | Y N |
| 18 When people shout at you do you shout back? | Y N |
| 19 Do you usually make up your mind quickly? | Y N |

NB. All items except 5, 16, and 17 score 1 point for a 'yes' response and zero for a 'no' response.

Items 5, 16, and 17 score 1 pint for a 'yes' and zero for a 'no.'

