Exploring attentional bias to food cues.

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Exploring Attentional Bias to Food Cues

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Submitted to Swansea University in fulfilment of the requirements for the Degree of Doctor of Philosophy

Swansea University

March 2012

Summary (Abstract)

The attentional system has evolved to be proficient at responding to the presence of food cues, particularly to those which are energy dense (Berthoud, 2007). Individuals who pay heightened attention to food stimuli within their feeding environment are likely to be motivated to overeat as a consequence. This current thesis presents 6 experiments which explore the extent to which paying enhanced attention to food cues in the environment influences eating behaviour. Experiment 1 established that individuals who are responsive to the pull of food cues, sensitive to reward and have high disinhibition are at risk of developing obesity. Experiment 2 demonstrated that individuals with high disinhibition were quicker to respond to high calorie food stimuli shown on a visual dot probe task. Whereas experiment 3 indicated that attentional retraining (learning to attend or avoid food stimuli on a visual dot probe task) could successfully manipulate food processing bias and calorie intake. Experiments 4 and 5 investigated the extent to which reward can determine the incentive salience of cues. Novel cues which had been paired with chocolate reward during a training task were found to elicited greater attention both at a behavioural and neurophysiological level. Finally Experiment 6 demonstrated that these trained cues could successfully manipulate craving. These results are discussed in terms of theoretical perspectives of attentional bias and the wider implications for understanding overeating.

Declaration and Statements

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed . ... (candidate)

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STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Where correction services have been used, the extent and nature of the correction is clearly marked in a footnote(s).

Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

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Acknowledgements

For Poppy Cari Williams x

First and foremost I owe my deepest gratitude to my supervisor Dr Michelle Lee. Your patience, expertise and creative approach to research has been invaluable, as has been the support and guidance you have offered across the course of my PhD. I would also like to acknowledge the support of the Psychology Department at Swansea, which through my teaching studentship has provided me with the necessary financial backing to conduct this research. Huge thanks also to Dr Nathalie Fouquet who was kind enough to guide me throughout my first attempts at conducting EEG research.

To all my friends, family and fellow PhD students; I am grateful for the support you have provided over the past few years. Rhys, I am privileged to have such a loyal and supportive husband and look forward to starting a new chapter in our life together with Poppy. Gemma, Thano and Shakelia we have procrastinated over endless cups of coffee, you guys have helped keep me sane! To my parents – thank you for your unconditional love, I hope that I continue to make you proud of me. Nanna – although you sadly passed away before I finished this work your encouragement was unfailing. I know that you would be overwhelmingly proud of my achievements. A final thank you goes to my dearest friends Dai, Hayley and Rebecca, although I have undoubtedly bored you with my work you have always been there to encourage me. Without the support from you all, this thesis would not have been possible.

Research Publications and Conference Presentations

- Seage, C. H (2009) The role of disinhibition in attentional bias to food stimuli. *Poster presented at the Welsh Institute of Cognitive Neuroscience (WICN) Summer Meeting.* Cardiff, UK June 2009

- Seage, C. H (2010) Can attentional retraining influence ad libitum intake and appetite sensations. *Paper presented at the British Feeding and Drinking Group Meeting (BFDG).* Maastricht, Netherlands, March 2010

- Seage, C H and Lee, M. D (2010) Manipulating attentional bias to food stimuli: can attentional retraining impact on ad libitum intake and hunger. *Poster presented at the Society for the study of Injestive Behaviour Annual Meeting (SSIB)* Pittsburgh, USA, July 2010.

- Seage, C H. (2011) The effect of motivational state and incentive salience of conditioned food cues on attention. *Poster presented at the Welsh Institute of Cognitive Neuroscience Annual Conference (WICN)*, Deganwy, Wales Jan 2011

- Seage, C H (2011) Attention to conditioned food cues. *Paper presented at the British Feeding and Drinking Group Meeting (BFDG).* Belfast, UK March 2011

- Seage, C H (2011) Understanding attention to food cues. *Paper presented at University of Birmingham Appetite Research Day*, Birmingham, UK. June 2011

- Seage, C H (2011) Exploring the role of conditioning in attention to food cues. *Paper presented at the Society for the study of Injestive Behaviour Annual Meeting (SSIB)* Florida, USA July 2011.

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Abbreviations

AB	Attentional Blink
ANOVA	Analysis of Variance
BAS_RR	Behavioural Activation System measuring reward responsiveness
BIS	Behavioural Inhibition System
BMI	Body Mass Index (kg/m^2)
CMS	Common Mode Sense
CNS	Central Nervous System
CS	Conditioned Stimulus
DBEQDEBQ	Dutch Eating Behaviour
DBEQDEBQ_EM	Dutch Eating Behaviour Emotional Eating Scale
DBEQDEBQ_EX	Dutch Eating Behaviour External Eating Scale
DBEQDEBQ_R	Dutch Eating Behaviour Restraint Scale
DRL	Driven Right Leg
DV	Dependent Variable
EEG	Electroencephalogram
ERP	Event Related Potential
FPB	Food Processing Bias
g	Grams
IV	Independent Variable
Kcal	Kilocalorie
Kj	Kilojoules
Mm	Millimeters
ms	Milliseconds
PFS	Power of Food Scale
PFS Available	The pull of available but not present foods
PFS Present	The pull of presented but not tasted foods
PFS Tasted	The pull of tasted but not consumed foods
RSVP	Rapid Serial Visual Processing
RT	Reaction Time
SD	Standard Deviation
SEM	Standard Error of the mean
T1	Target 1
T2	Target 2
TFEQ	Three Factor Eating Questionnaire
TFEQ_D	Three Factor Eating Questionnaire Disinhibition Scale
TFEQ_H	Three Factor Eating Questionnaire Hunger Scale
TFEQ_R	Three Factor Eating Questionnaire Restraint Scale
US	Unconditioned Stimulus
VAS	Visual Analogue scale
VDP	Visual Dot Probe
WICN	Wales Institute of Cognitive Neuroscience

Chapter 1

General Introduction

1.1 General Introduction

Rising obesity rates are a worldwide health concern; recent estimates propose that there are 1.46 billion adults worldwide classified as overweight (BMI >25 kg/m2) with 502 million of these being obese (BMI >30 kg/m2) (Finucane et al. 2011). Without successful intervention it is predicted that by 2020, seven out of ten adults in the UK and three out of four American adults will be classified as obese (Sassi, 2010). The long-term negative health complications associated with obesity are extensive and include elevated risk of developing type 2 diabetes, metabolic deficiency, cardiovascular disease, infection and cancers (Guh, 2009; Jafar, Chaturvedi & Pappas, 2006; Knowler, 1983; Manson et al.1992a; Manson et al. 1992b; Whitlock et al., 2009; Wolin, Carson, & Colditz, 2010; Wolin & Colditz, 2008).

An additional burden to the health service is the increasing costs associated with caring for an obese population; estimates of health expenditures within the NHS propose that £ 4.2 billion each year is spent on caring for obese patients (Department of Health, 2011). The emergence of this so-called obesity "epidemic" has been attributed to environmental and societal changes within the modern food environment. Hill, Wyatt, Reed and Peters (2003) coined the phrase "obesogenic environment" to describe this appearance of ubiquitous marketing of energy dense foods, increased portion sizes and reduced energy expenditure within developed society. This heighted prevalence of food cues could act to directly stimulate overeating and therefore promote obesity (Hill et al. 2003). Hetherington (2007; page 113) proposed that in order to understand overeating "it is important to identify the controls of ingestion which are influenced by the food environment and examine how these features operate to derail homeostatic control....."

The attentional system has evolved to be proficient at responding to the presence of food cues, particularly to those which are energy dense (Berthoud, 2007). Individuals who pay heightened attention to food stimuli within their feeding environment are likely to be motivated to overeat as a consequence. Overeating is considered to be one of the most accurate predictors of obesity (Westerterp & Speakman, 2008). Almost all individuals living within western society are exposed to salient food cues on a daily basis, therefore it has become pertinent to explore how these elements of the food environment interact with homeostatic control and promote overeating. Equally it is important to establish the factors which differentiate individuals who are driven to overeat in the presence food cues from those who are not? To address this question it is imperative to study the role of attention in feeding behaviour. This chapter aims to provide a detailed account of how attentional mechanisms contribute to overeating. In particular focusing on how the attentional system interacts with reward processes to promote non homeostatic feeding.

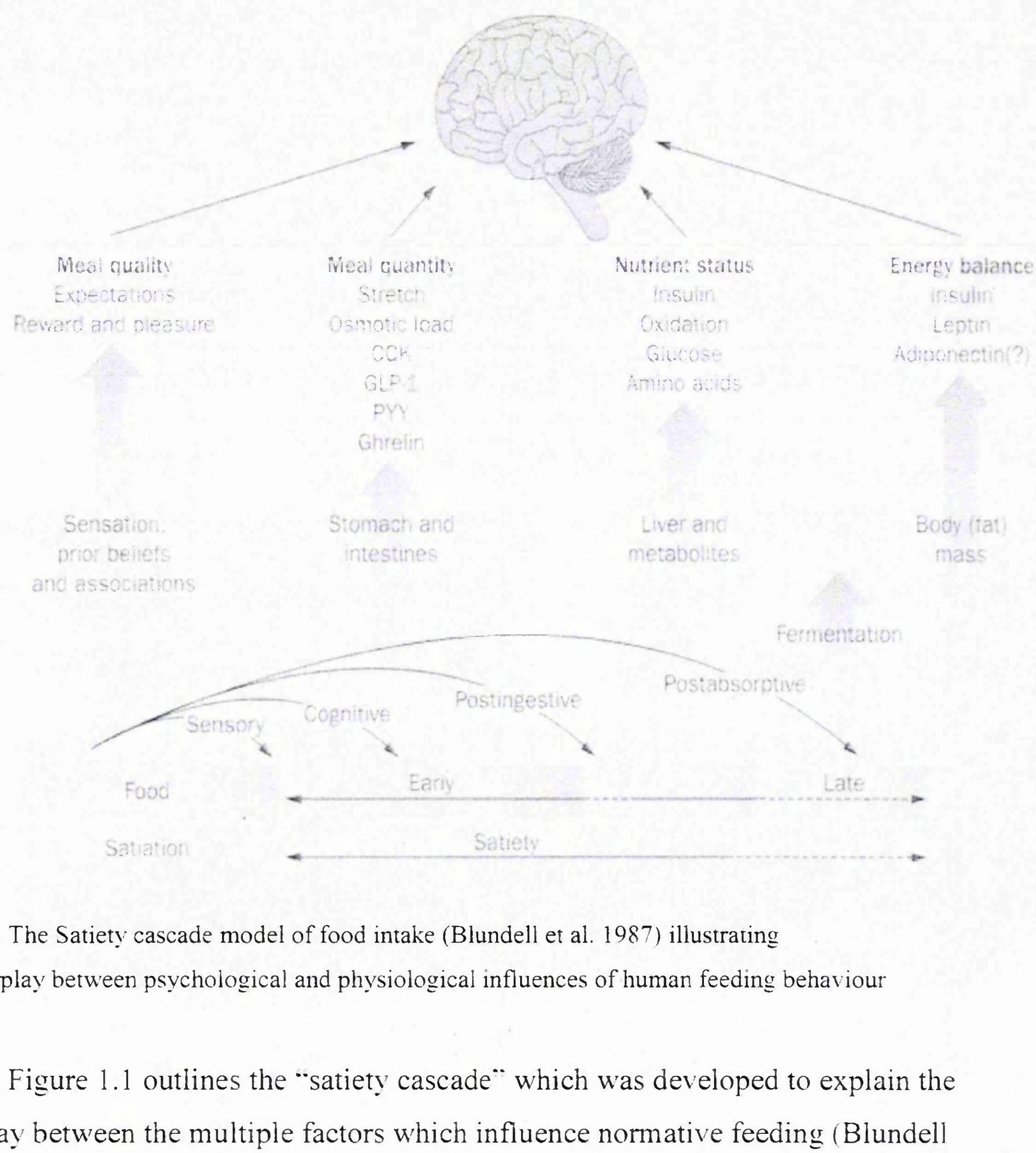
1. 2. Conceptualizing the control of food intake

In order to formulate an in-depth understanding of obesity's epidemiology it is imperative to firstly identify the factors which influence normal human food intake. Conceptualisation of human feeding behaviour appears to more complex than what is proposed by models of animal feeding, which are strongly underpinned by physiological control. Historically appetite research has focused on identifying the biological mechanisms that underpin food intake (Blundell et al. 1987). Control of feeding behaviour was attributed to the homeostatic system which maintains balance between energy intake and energy expenditure. These mechanisms evolved in an environment where there was limited food availability, and therefore serve to promote positive energy balance and repletion of energy stores (Saper, Chou & Elmquist, 2002). The neural network associated with this system has been extensively mapped; key regions are the brainstem and hypothalamus which are often referred to as the "metabolic brain" (Ahima & Antwi, 2008).

Homeostatic control can be differentiated into processes which control short term "episodic" food intake and longer term "tonic" regulation (Blundell & Finlayson, 2004). Episodic mechanisms regulate food intake on a meal by meal basis, therefore the term is often used to refer to processes associated with signals of hunger and satiety. "Tonic regulation" is responsible for the long term maintenance of bodyweight, it is these mechanisms which establish equilibrium between energy intake and expenditure, whilst taking into account fat stores (Smith & Ferguson, 2008). Interaction between these two systems enables calorie intake based on short term or long term needs. Extensive review of these mechanisms are beyond the remit of this thesis; however it is important to emphasise that the homeostatic system is highly efficient at increasing food intake during times of energy deficit (Saper, Chou & Elmquist, 2002). Whereas the metabolic brain's ability to reduce food intake and increase energy expenditure when food is in abundance appears limited (Berthoud, 2007). From a purely homeostatic perspective the propensity to gain weight can be conceptualised as a consequence of underlying dysfunction at either or both of these levels (Mela, 2006). Overeating is subsequently viewed as a consequence of "flawed" interpretation of appetite sensations or deficits in hormonal control (Rolls, 2007). Research manipulating homeostatic control in animals consistently demonstrates that such deficits lead to elevated body weight and hyperphagia (for review see Williams, Harrold and Culter, 2000). For example, administration of the neurotransmitter Agmatine has been shown to increase feeding in rats, where as Agmatine antagonists inhibit hyperphagia (Taksande et al. 2011).

Although it is hard to dispute that the homeostatic system enables tight regulation of feeding in animals. The degree to which the animal literature can be used to understand human eating behaviour can be debated. The systems that regulate or control eating behaviour in humans are more complex, because psychological and cognitive factors are also important.

Figure 1.1:



The Satiety cascade model of food intake (Blundell et al. 1987) illustrating the interplay between psychological and physiological influences of human feeding behaviour

Figure 1.1 outlines the "satiety cascade" which was developed to explain the interplay between the multiple factors which influence normative feeding (Blundell et al. 1987). Figure 1.1 displays the time course from the instigation of feeding to satiation. Early motivation to feed may stem from sensory signals such as the sight and smell of food which elicit physiological responses (e.g. dopamine release, insulin release). However cognitive factors may also motivate an individual to begin feeding; learning (Brunstom, Downes, Higgs 2001; Brunstom, Higgs and Mitchell, 2005), memory (Higgs 2008; Higgs and Woodward, 2009) and attention (Herman and Polivy, 2004) have all been be heavily implicated in human food choice and intake. As well as cognitive factors, the social environment is also influential, for example decisions about intake and food choice may be modelled on a social companion (Bevelander, Anschutz and Engels, 2011) or be a product of impression management (Pachucki, Jacques and Chritakis 2011). Finally increased interest in the obesogenic environment has demonstrated that the built environment can influence appetite motivation; determinates of food choice include food cost (De Irala-Estevez et al. 2000) and physical proximity to food suppliers (Dibsdall, Lambert, Bobbin and Frewer, 2003). The modern food environment can also provide a social context in which feeding continues despite the presence of metabolic cues to cease intake. Such behaviour is often considered to be consequential of the modern lifestyle. Therefore these environments are often seen as encouraging prolonged eating or drinking simply for "pleasure" (Lowe and Butryn, 2007).

The multiple factors influencing feeding outlined above indicate that although homeostasis may once have directly driven human food intake this does not seem to be valid within the modern food environment. Thus in recent decades exploration of the "non homeostatic" factors which influence overeating has gained popularity (Berthoud. 2007; Blundell & Finlayson, 2004; Lowe & Butryn, 2007). Non homeostatic controls of appetite are considered to be more central in human feeding than they have in previous years; thus they have been the focus of a number of recent review papers (Berthoud, 2007; Blundell & Finlayson, 2004; Lowe & Butryn, 2007). These reviews implicated a number of non homeostatic factors influence human food intake, these may be environmental, emotional or social in nature. The body of work by Berthound (Berthoud, 2003, 2004a, 2004b, 2005, 2006, 2007, 2011) proposes a dynamic interplay between what he terms the "hedonic" (non homeostatic) brain and the metabolic brain. However the extent of assimilation between these two neural systems remains under debate. As does consensus in regards to which system (if either) exerts the most influence over human feeding behaviour (Berthoud, 2007; Blundell & Finlayson. 2004; Lowe & Butryn. 2007).

In line with current perspectives this thesis considers the control of human food intake to be dualistic. It is proposed that a result of the emerging obesogenic environment is that non homeostatic systems have gained increased influence over food intake. In particular, the heightened availability and salient marketing of energy dense foods has increased the extent to which attention is implicated in the control of eating behaviour. This thesis aims to specifically focus on one aspect of cognition which has been shown to influence food intake, which is attention. This body of work is centred on the proposition that the obesogenic environment has increased the motivational value of food cues (through associative learning) (Robinson and Berridge, 1998). Possible consequences of this are that greater attentional processes are allocated to the processing of food based information. This thesis aims to explore the extent to which behavioural differences in attention to food cues are linked to a propensity to overeat. This work will additionally explore the degree to which responsivity to food cues in the environment is mediated by bottom up processes (emotion/reward) and top down processes (cognitive controls) (See Figure 1.2)

Figure 1.2 :

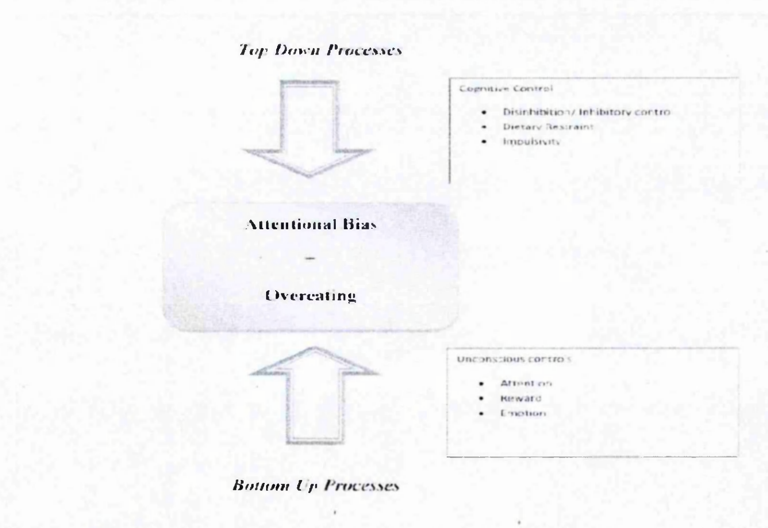


Diagram outlining the top down and bottom up processes which may influence the extent to which food processing bias is expressed through overeating

1. 2. The role of attention in eating behaviour

Attention is a selective process that allows an individual to concentrate on specific aspects of their environment whilst ignoring irrelevant information. Sustained attention is important to goal seeking behaviour; such processes may be knowledge driven [top down] or stimulus driven[bottom up] (Sarter et al. 2001). Subsequently, the attentional system has evolved to preferentially allocate resources to the processing of salient cues in the environment; these may indicate threat, be biologically relevant (indicating availability of resources) or be congruent to current goals (For review see Vuileumier, Armony and Dolan, 2003). Food stimuli are a pertinent feature of the food environment with their presence being indicative of food availability. The majority of food cues are sensory in nature (i.e. sight, aroma,) however in obesogenic environments food cues may also be related to social contexts or learned associations (e.g. logos associated with well know food brands) (Berthoud, 2007).

Although there is behavioural evidence that cues can modulate behaviour even when not directly attended to (Hogarth. Dickinson. Janowski. Nikitina, & Duka, 2008). The extent to which attention is allocated to food cues often depends on motivational relevance. A robust finding within appetite research is that participants generally consider the saliency of food cues to be lower when satiated, however these same cues are able to act as incentive stimuli when the individuals are hungry (e.g. Cornier, Grunwald, Johnson, & Bessesen, 2004; Mogg, Bradley, Hyare, & Lee, 1998; Small, Zatorre, Dagher, Evans, & Jones-Gotman, 2001; Tapper, Pothos, & Lawrence, 2010). Equally, heightened attention is allocated to cues which signal the availability of foods which have high energy density (Cornier, Von Kaenel, Bessesen, & Tregellas, 2007). The presence of palatable food stimuli have been shown to directly influence consumption, elicit anticipatory responses and increase the desire to eat (Jansen et al. 2003). Exposure to food stimuli in experimental contexts frequently promotes overeating and craving (Bobroff and Kissileff, 1986; Fedoroff et al. 1997; Jansen et al. 2003). Evidence from Hogarth et al. (2008) suggests that cues can manipulate behaviour even when they are not directly attended to, this automaticity may lead to eating in situations where individuals are not actually hungry.

There is considerable support within the appetite literature to claims that individuals who are obese (or at risk of developing obesity) are considerably more responsive to food cues within the environment (Caltri, Pothos, Tapper, Brunstrom and Rogers, 2010; Epstein, Paluch, & Coleman, 1996; Johnson and Wildman, 1983; Supporting this idea, a recent publication by Caltri et al. (2010) demonstrated that indices of food cue reactivity are able to predict weight gain over a twelve month period. Therefore outlining the process through which food stimuli capture attention and subsequently promote intake appears to be imperative to understanding the aetiology of obesity.

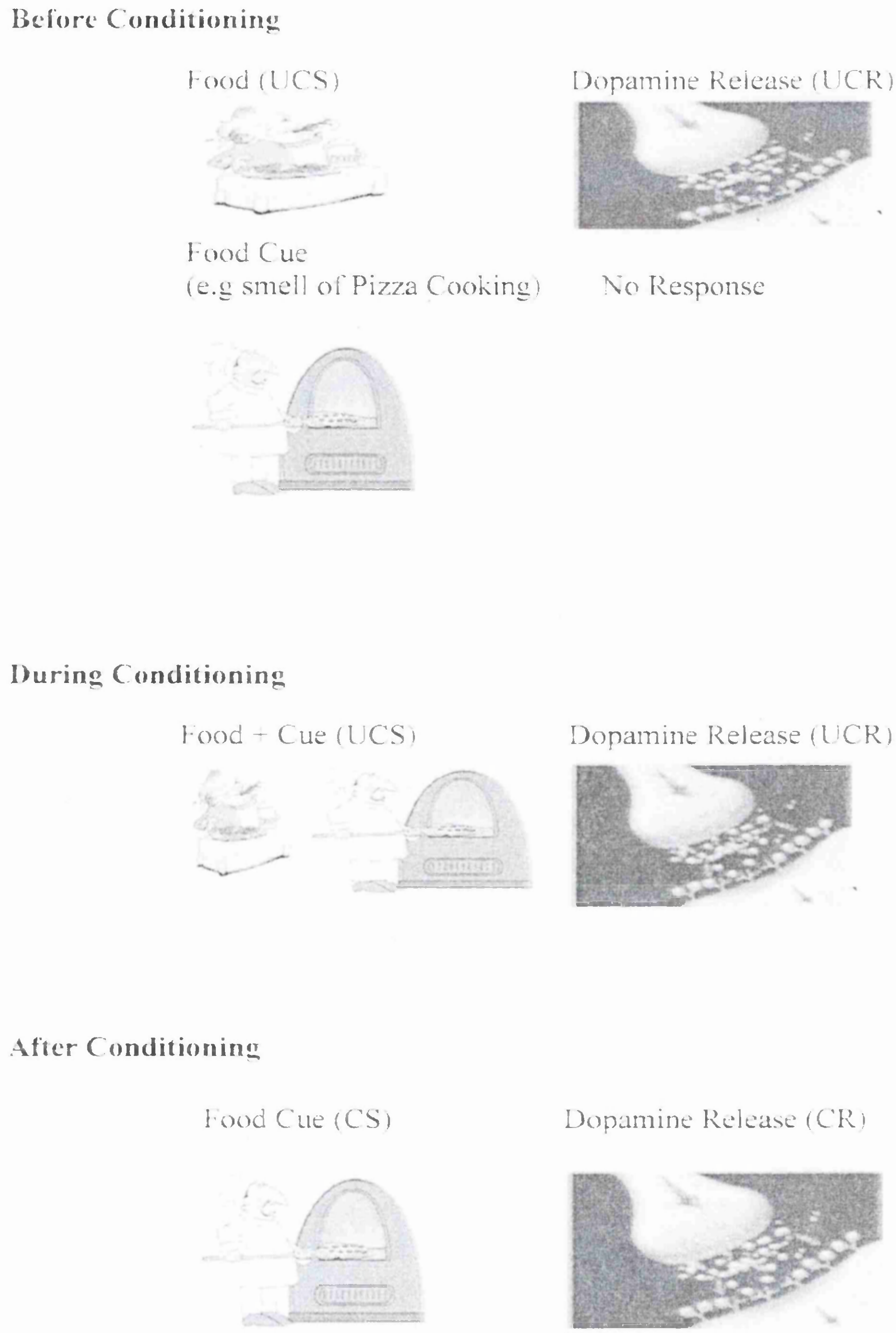
To understand fully the relationship between attention and overeating it is important to acknowledge the role that dopamine plays in motivation and goal seeking. Behaviour in humans and animals is often determined by their motivation to seek out reward; be this through engaging in sex, consuming food or experiencing pleasure (Kringlebach and Berridge, 2010). Goal seeking behaviour develops as a result of associative learning; stimuli associated with goals develop increased motivational value as their presence is reinforced by dopamine release within the brains reward systems. One of the first studies demonstrating this effect was conducted by Olds and Milner (1954). Their research showed that rats were able to learn that a specific pattern of responses would lead to electrical stimulation within the brain. This electrical stimulation of the reward system reinforced the rat's behaviour as it elicited the release of dopamine into the nucleus accumbens (Kalat, 2004). Over recent decades researchers have gained a more in-depth understanding of dopamine's role in goal directed behaviour (for review see Wanat, Willuhn, Clark and Phillips, 2009). To summarise, this research has clearly demonstrated that goal directed behaviour can be reinforced through associative learning. Neutral stimuli (cues, objects, people, places etc.) gain increased incentive value through conditioning and thus future encounters with these stimuli activates reward circuitry and motivates approach behaviours. The following section will outline the current theoretical consensus of how cues develop increased incentive value and how this saliency may relate to attentional bias.

1.4 Theoretical accounts of cue saliency

There are a number of theoretical accounts which outline how cues gain incentive properties. Many of these theories originate in the addiction literature and attempt to explain the link between stimulus perception and subsequent drug use. Substance dependency is associated with heightened attention for relevant cues (i.e. attentional bias) and predictable physiological or cognitive responses (i.e. cue reactivity) (for review see: Field, Munafò & Franken, 2009). These effects are mirrored within the food cue reactivity literature which will be referred to throughout this thesis. It is useful to draw parallels between the obesity and addiction literature; from this standpoint overeating can be considered to be the direct consequence of heightened reactivity to food stimuli.[It can be hypothesised that food stimuli gain increased incentive value in individuals who habitually overeat]. For these predictions to be substantiated, obesity should subsequently be characterised by biased processing of food relevant information and enhanced reactivity to food cues].

Addiction based models are equally applicable to understanding how food stimuli become salient (Berridge, 2009). A commonality between many of these accounts is that they consider the incentive properties of cues to develop as a direct consequence of dopamine release within the nucleus accumbens. Classical (or Pavlovian) conditioning is the process during which a neutral stimulus becomes associated with reward. Figure 1.3 outlines how conditioning processes increase the incentive properties of cues. Here it is seen that repeated pairing of a neutral stimulus (Unconditioned Stimulus, US) with dopamine release within the nucleus acumens increases neural activity associated with the CS. The CS subsequently codes the reward value of the US and generates a predictable behavioural response (Conditioned Response, CR). In regards to the addiction literature it is thought that physiological effects of rewarding substances (CS) become associated with cues which are consistently present at the time of drug administration (US). Consequently drug cues become predictive of drug administration but also the psychoactive effects of the drug. Following repeated exposures, drug cues begin to elicit conditioned responses (cue-reactivity, physiological responses) but also command greater attention (attentional bias). In a naturalistic environment, drug cues can include drug related paraphernalia, drug related cognitions and the contextual environment in which the drug is used. All of these have been shown to capture attention and generate conditioned responses in substance users (Field, Munafò & Franken. 2009).

Figure 1.3 :



Schematic diagram outlining how dopaminergic conditioning increases the salience of food cues (Adapted from Robinson and Berridge, 1998)

1.4.1 Incentive sensitization theory

The incentive sensitization theory by Berridge & Robinson (1998) proposes that rewarding substances and their related cues acquire increased salience through classical conditioning. On a physiological level this is a result of repeated dopamine release into the nucleus accumbens paired with the presentation of reward predictors. Frequent pairing of rewarding substances with their related cues results in the cue's themselves become enhanced motivational targets. Overtime this heightened salience results in increased attention being allocated to the cues: this is depicted as "a spot light of attention" (Berridge & Robinson, 1998). Enhancing the motivational salience of a cue alters the way in which it is perceived by the substance user; this is reflected behaviourally as attentional bias (quicker detection of rewarding cues in cognitive tasks) but also on a physiological level (cue reactivity). The presence of cues often indicates to the user that a substance is available, thus further motivating the individual to seeking out the desired substance. The presence of drug cues often correlates with increased "wanting". Elevated craving is viewed as the "emotional" consequence of dopaminergic conditioning (Berridge, Robinson, & Aldridge, 2009) . Whereas attentional bias is considered to be a cognitive consequence of conditioning. To summarise the increased motivational value of salient cues induces hyper vigilance for other drug cues within the environment but also increase craving. Both of these effects are likely to influence drug seeking and maintain addictive behaviour.

Although the incentive sensitization theory (Berridge & Robinson, 1998) originated as a theoretical explanation of how drug use is maintained. In recent years Berridge and colleagues have applied this theory to explain how food cues become motivational targets (Kelley & Berridge, 2002). In accordance to their theory overeating can be considered to be the direct consequence of repeated exposure to foods which are high in reward. Sensitization within the dopaminergic system leads to increased approach behaviours (and craving) for hedonic foods but also increases the incentive properties of food stimuli. This is likely to result in increased craving and overconsumption of foods which are highly rewarding (Berridge, 2009). Although cue reactivity and attentional bias may not be maladaptive from an evolutionally standpoint, their effects on feeding may be amplified in an obesogenic environment. A consequence of this is that individuals will be motivated to consume high calorie foods even in contexts where energy deficits are not experience.

A drawback of perspectives such as Berridge's is that they do not as yet explain why individual differences are seen in regards to cue reactivity/ attentional bias. Similarly the degree to which experiencing "wanting" and "liking" leads to overconsumption in the general population remains understudied. In regards to habitual overeating / binge eating these behaviours could be viewed as a direct consequence of dysfunction within the reward circuitry. For example if hedonic hotspots within the nucleus accumbens are over stimulated by reward it is probable that the individual will experience elevated reactivity in the presence of hedonic food cues (Berridge, 2009). Robinson and Berridge (2009) propose that these processes occur within sub cortical regions of the brain. These areas are linked to the control of basic innate functions. This theoretical account suggests incentive salience is unlikely to be based around conscious cognitions or expectations. Incentive salience is instead better viewed as a naive, instinctive response to reward (Berridge, 2009). However the degree to which incentive sensitization is a cause or consequence of obesity remains unclear.

1.4.2 Theoretical accounts of cue reactivity (Tiffany, 1999)

The non associative model of drug use and drug urges (Tiffany & Carter, 1998) outlines that all drug cues (regardless of specific drug type) are able to generate a general physiological response. Tiffany's body of work (Tiffany, 1999; Tiffany & Carter, 1998; Tiffany & Conklin, 2000) was developed following a meta-analysis of findings within the drug cue-reactivity literature. This demonstrated that substance users robustly displayed increased heart rate and skin conductance in response to drug cues (Tiffany & Carter, 1998). This theory proposes that drug cues in the environment activate "drug action" schema, which in turn trigger thoughts and cognitions focused on drug seeking. Exposure to drug cues therefore leads to an increased urge to consume the drug itself, this urge is thought to reflect what substance users label as "craving". Cue-elicited craving is a central feature of Tiffany's (1998) account of cue-reactivity. The term depicts the elevated desire for a rewarding substance, and is thought to be a consequence of being exposed to drug cues. From this perspective, heightened attention for drug cues within the environment is thought to be directly driven by craving. .

Although originating within the addiction literature the overlap between the ideas proposed by Tiffany (1999, 1998, 2000) and accounts of habitual overeaters/

binge eaters is apparent. Food craving or preoccupation with thoughts about food is a characteristic of dieting. Based on the principles outlined in the non associative model of drug use and drug urges Jansen (1998) developed the "conditioning model of binge eating". Akin to Tiffany's approach. this model considered incidences of binge eating to be a consequence of cue elicited craving. As with substance use, food craving is viewed as a conditioned physiological reaction to the presence of food stimuli within the environment. Jansen (1998) identified a number of disinhibitors which act as conditioned stimuli (i.e. the smell of palatable foods, thoughts about binge eating, taste of palatable foods). These generate cued-craving and subsequently serve as motivators to overeat. Jansen (2003) demonstrated that overweight children were more susceptible to overeating in the response to food cues; the children's behaviour supported the prediction that associative learning is strongest in overweight individuals. Work by Fedoroff and colleges (2003) also provides empirical support for this theory; in this study participants were exposed to the smell of pizza or cookies cooking in an oven prior to a measure of ad libitum intake. The disinhibiting effects of these cues were more pronounced in restrained eaters: who consumed significantly more of the cued food. Correspondingly, restrained eaters reported increased craving, liking and desire for the cued food (Fedoroff, Polivy & Herman, 2003).

1.4.3 The role of craving in cue saliency

Franken (2003) expanded the concepts outlined in the incentive sensitization model (Robinson and Berridge, 1993) by further detailing the involvement of craving. As seen in the previous section (1.4.2) craving is considered to be a central feature of both substance dependence and binge eating. Franken (2003) proposed that the enhanced attentional processing elicited as a response to salient cues, are influenced by but also promote craving. A bi-directional relationship is proposed between attentional bias and craving, this is that "both are able to modulate each other" (Franken, 2003, pg 532). In line with the accounts proposed by Robinson and Berridge (1999) attentional bias is viewed by Franken (2003) to be caused by increased dopamine release within the nucleus accumbens in response to cue/ reward pairing. Craving is a consequence of this dopamine release, and it is the experience of craving which enhances the motivational properties of cues. Therefore from Franken's (2003) perspective craving can directly influence attentional bias.

Paying heightened attention to cues has a number of important implications in relation to maintaining addictive behaviours. Enhanced signalling not only increases the attentional processing of the original cue, but also increases the likelihood that attention will be paid to new cues in the environment (Franken, 2003). The link between attention and craving has further implications for substance related cognitions. For example craving is likely to be reflected behaviourally as memory biases (Franken, Rosso, and Honk, 2003) or the experience of obsessive thoughts and preoccupation. These processes limit the attentional resources left to process alternative cues. In the context of eating behaviour this could be at the expense of engaging with internal cues signalling that there is no energy deficit or reminders of dieting goals. Experiencing attentional bias and craving subsequently limits the resources which can be allocated to counter strategies that may help prevent overeating (Franken, 2003).

1.4.4 Theory of current concerns (Klinger and Cox, 2004)

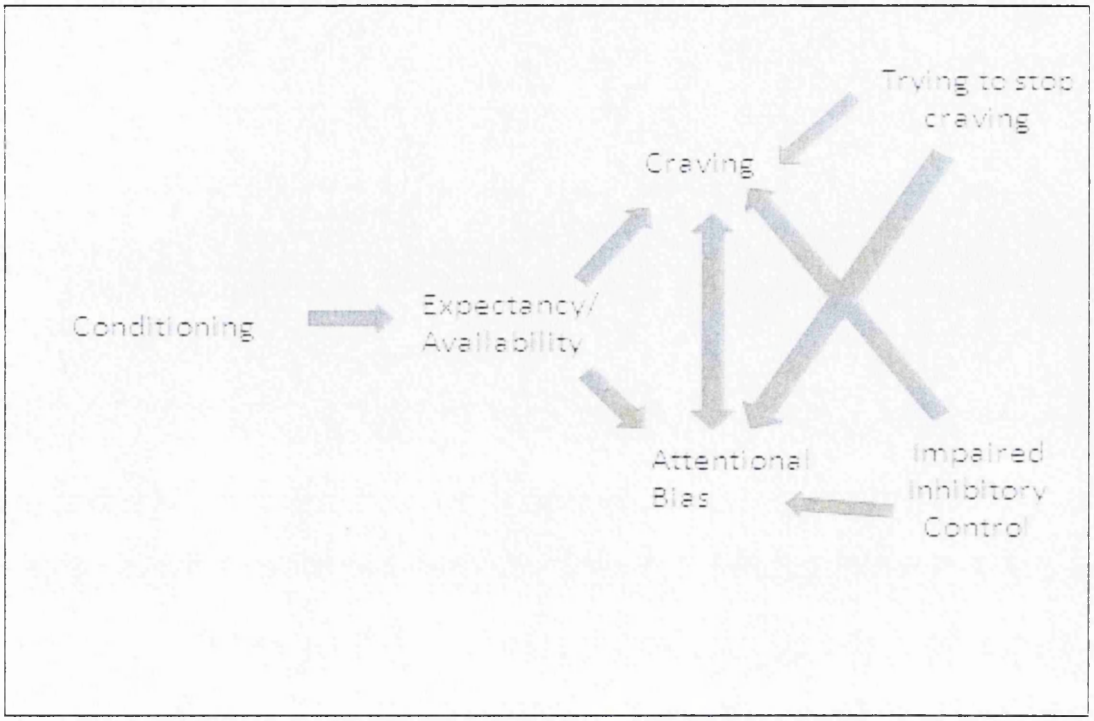
The theory of current concerns provides an alternative account of why more attention is allocated to some cues in the environment rather than others. This approach is based on the principle that the essence of life is the pursuit of goals, and thus daily life is categorized around "incentives" that are salient to the individual. Cox and Klinger (2004) propose that pursuing goals generates a motivational state which they term a "current concern". Focusing on current concerns leads to bias when processing information, this is that an individual is more likely to attend to information in their environment that is relevant to their current concern. For example, an individual who wishes to purchase a new car may suddenly report that they see the model they wish to purchase "everywhere". Goal relevant information is prioritised within the attentional system and this is why heightened awareness is reported for relevant stimuli or cues. In turn current concerns increase the frequency of goal related thoughts, which further enhances the salience of relevant cues. This account provides an alternative explanation for why food cues appear to be the most salient when an individual is hungry (Cornier et al. 2007; Mogg, et al., 1998, Small, et al., 2001, Tapper et al. 2010). But can also be used to understand why preoccupation with food is commonly experienced when dieting. Food information is likely to gain increased priority for individuals whose goals are focused on weight loss or calorie intake. This theory subsequently explains why paradoxically, dieters often report frequent food thoughts, heightened awareness of food cues and increased craving.

1.4.5 Field and Cox (2008) Theory of Attentional Bias

Field and Cox (2008) developed their theory of attentional bias which attempted to bring together the key theories in the literature (e.g. Franken, 2003, Robinson and Berridge, 1993). Their review of the role of attentional bias in addictive behaviour showed that dependent users of heroin, cocaine, alcohol, nicotine, cannabis and caffeine all displayed heightened attention for drug cues (Field et al. 2009). A meta- analysis of 68 studies found a direct relationship between attentional bias and craving. Although the overall correlation between these two variables was weak (r=0.19) an in-depth analysis demonstrated that this relationship was mediated by drug type but also the measure of attention used. This relationship did not appear to be effected by treatment status.

Field and Cox (2008) synthesised the proposals of previous theories to provide a working model of how attentional bias influences drug seeking behaviour. Consistent with previous accounts, the model proposes conditioning within the dopaminergic system is responsible for cue saliency. When drug cues are present within the environment this produces an expectation of substance availability; on the basis of these expectation substance users will begin to experience craving and pay heightened attention to relevant cues. This model is summarised in Figure 1.4; although Field and Cox consider craving and attentional bias to be independent, a reciprocal relationship is proposed between the two. This is that experiencing craving may lead to increase attentional bias, however equally attentional bias may lead to increased reports of craving. Expectancy mediates these processes; as attentional bias and craving is likely to be lower in contexts where there is no access to the desired substance. Field and Cox (2008) put forward a number of additional cognitive factors which are likely to influence attentional bias/ craving. Individuals may employ coping strategies to suppress craving and cognitive bias; these may be successful in deterring substance use or counteractive enhancing cognitive processes. The latter proposal is similar to what is outlined in the current concerns theory (1.4.4) and is likely to increase craving and attentional bias. Additionally this model proposes that attentional bias and craving will be heighted in individuals who display deficits in inhibitory control.

Figure 1.4:



Schematic diagram summarising the key concepts of the integrated model of attentional bias adapted from Field and Cox's (2008, pg 18) "Attentional bias in addictive behaviours: A review of its development, causes, and consequences".

1.5 The influence of food cues on feeding behaviour

Section 1.4 outlined how dopaminergic conditioning increases the incentive properties of rewarding cues (Field and Cox, 2008, Franken, 2003, Robinson and Berridge, 1993). As a consequence, food cues in the environment could have higher salience for individuals who are susceptible to and/or overeat. Attentional bias may also lead to increased craving and approach behaviour. Subsequently an obesogenic environment may be particularly challenging for a number of at risk groups. There is an increasing body of evidence supporting the prediction that overeating is directly related to how susceptible an individual is to eating in response to food cues in their environment (Epstein et al. 1996; Caltri, Pothos, Tapper, Brunstrom and Rogers, 2010; Halford, Gillespie, Brown, Pontin, & Dovey, 2004; Herman, Ostovich, & Polivy, 1999; Herman & Polivy, 1990; Johnson & Wildman). This relationship can be explored behaviourally by measuring cue-reactivity, attentional bias and reported craving. A number of sub groups report that their eating behaviour is frequently influenced by the presence of food cues. These include individuals who are currently overweight (or obese) (Halford, Gillespie, Brown, Pontin, & Dovey, 2004; Johnson and Wildman, 1983) and those who have a genetic propensity to gain weight (e.g. Epstein et al. 1996; Herman & Polivy, 1990) As increased attention is often paid to goal relevant information it can also be predicted that individuals who are focused on dieting goals will also be susceptible to overeating in the presence of food cues (Fedoroff, et al 2003; Fedoroff, Polivy, & Herman, 1997; Nederkoorn & Jansen, 2002; Overduin, Jansen, & Eilkes, 1997). This paradoxical relationship has important implications for individuals who have previously been obese and are trying to maintain a healthy body weight, and for current dieters/ restrained eaters. The effects of exposing these groups to salient food will be reviewed in more detail in section 1.5.3.

Thinking about obesity as the direct consequence of enhanced responsivity to food cues is not a new proposition. Since the 1960s theorists have attributed overeating and subsequent weight gain to individual differences in reactivity to food stimuli (Schacter, 1968). The "externality theory of human obesity" proposed a theoretical framework of weight gain vulnerability which was focused on examining the external factors which motivate a person to feed (Schacter, 1968). Maintenance of a healthy body weight was believed to be reliant on individuals eating only in response to internal cues (hunger or satiety). However Schachter (1968) anticipated that there was a subpopulation of individuals whose appetite was not driven by homeostatic control; he called these "external eaters". For external eaters food intake is motivated primarily by the presence of food stimuli (sight, smell or taste of food). Schachter (1968) predicted that external eaters' susceptibility to weight gain was a direct consequence of them eating in response to the presence of food cues. This theory was highly influential in its time, spurring a series of behavioural experiments comparing the intake of obese and normal weight participants in response to food cues. In line with his prediction, these experiments demonstrated that intake was more prouncely effected by the presence of cues in obese participants (Schachter 1974). In another classic study participants were asked to taste and rate five difference crackers but were told they could eat as much of these crackers as desired (Schachter, 1968). In his control condition intake corresponded to the initial prediction that obese participants would not respond to internal appetite signals. Only the lean participants reduced their intake in response to a preload. However when Schachter later manipulated fear, lean participants still reduced their intake however the obese participants were found to increase their intake. This again supports Schachter's argument that obese individuals misinterpret internal signals as being related to appetite.

However knowledge around the exact mechanisms that allow external cues to override homeostatic control remained limited (Milich, 1975). As did existent of strong empirical evidence to substantiate Schachter's theory. (Hibscher & Herman, 1977; Hill & McCutcheon, 1975; Hörchner, Tuinebreijer, & Kelder, 2002; Meyers, Stunkard, & Coll, 1980; Rodin & Slochower, 1976; Rodin, Slochower, & Fleming, 1977) Meyers, Stunkard and Coll (1980) designed a naturalistic observational study, where they compared responsiveness to external food cues (high calorie or low calorie desserts) across obese and normal weight participants. This like much of the research into externality found that being highly responsive to the presence of food cues was not dependent on body weight. Despite the flaws of externality theory, the appetite literature has found some evidence that exposure to palatable food cues has a powerful influence on feeding behaviour. The following section will outline the literature demonstrating that food cues in the environment are able to directly increase food intake and also influence anticipatory appetite behaviours.

Weingarten and colleagues were one of the first research groups to demonstrate that food cues can instigate feeding even in the absence of nutritional deprivation (Weingarten & Elston, 1990; Weingarten & Watson, 1982). Their experimental paradigm conditioned rodents to associate a novel external cue with the presence of food (Weingarten and Watson, 1982). Exposure to the conditioned cue (CS+) was able motivate the rats to feed even when saited; this behaviour appears to mimic external eating in humans. Research into cue potentiated feeding is based around the principle that food deprived animals (often rodents) can be trained to associated a conditioned stimulus (auditory/visual cue) with an unconditioned food stimulus. There is a wealth of literature outlining factors which influence cue potentiated feeding in non humans however an in-depth discussion of this literature is beyond the remit of this thesis (for review see Petrovich, Ross, Holland & Gallagher, 2007) Importantly the effects of conditioning appear to be limited to the specific US used during training (Holland & Petrovich 2005, Petrovich et al. 2007). Increased intake was only demonstrated for the food pellets used during training and did not correspond to any other familiar foods placed in the same context (Holland & Petrovich, 2005; Petrovich et al., 2007). These findings suggest that exposure to conditioned cues does not induce a general motivation to eat but rather promotes the urge to consume a specific food item. This could be thought of as analogous with craving.

The same research group has identified the pathways which are central to cue potentiated eating in rats. Holland & Petrovich (2005) injected a retrograde trace flurogold into rats which had been trained to predict the availability of food from auditory cues. In vitro examination revealed that the lateral hypothalamus, amgydala and the prefrontal cortex were activated after exposure to conditioned cues. These areas are associated with processing reward and motivation. Lesions within the amgydala predicted unsuccessful acquisition of cue-potentiated feeding (Holland, Petrovich, & Gallagher, 2002). As theoretical accounts of cue saliency, also implicate the amgydala in the coding of pleasure (e.g. Robinson and Berridge, 1999) this provides further support for the prediction that learnt responsively is dependent on motivational value.

The effects of cue potentiated feeding have been replicated in human subjects. However the number of publications within this area is limited (Birch, McPhee, Sullivan & Johnson, 1989: Cornell, Rodin, & Weingarten, 1989). Birch et al. (1989) trained children to associate the intake of snack foods (US) with a visual and auditory cue (CS+). Additionally they were also trained to associate the absence of snack foods with a different visual and auditory cue (CS-). When saited more snack foods were consumed in the presence of the CS+ and less in response to the CS-. These effects appeared to be directly dependent on awareness, as consumption of children who did not learn the association between US/CS did not conform to this pattern. These effects were only partially replicated in adults (Cornell, Rodin and Weingarten, 1989). Hungry or satiated adults were trained to associate a novel cue with either the taste of chocolate (M&M's), sight of chocolate (picture of M&M's) or cognitions about chocolate (generated by reading a passage describing M&M's). This study demonstrated that although both the visual and taste CS resulted in increased report desire to eat, no significant differences were found in intake (Cornell, Rodin and Weingarten, 1989).

The majority of human research measuring the influence of food cues on intake is based on the assumption that humans already display conditioned responses to "liked" food cues. Therefore cue potentiated feeding in the human literature is more commonly investigated using a methodology known as "priming". In this paradigm participants are exposed to food cues prior to a measure of ad libitum intake (usually of energy dense food items). The cues used to "prime" participants may be sensory in nature (sight and smell) but also include food thoughts or words. Alternatively some studies expose participants to the food cue in the form of a preload, this is when participants are required to consume a small portion of a palatable food item (often a milkshake) prior to completing a task measuring intake (Herman and Mack, 1975 as cited by Nederkoorn & Jansen, 2002).

In priming research exposure to food cues is consistently found to increases calorie intake within laboratory settings (Fedoroff et al. 1997). Priming with palatable food cues is considered to be a strong predictor of both binge eating and overeating (Bobroff & Kissileff, 1986; Fedoroff, et al. 2003; Fedoroff et al.1997; Kissileff, 1986; Kissileff, Walsh, Kral, & Cassidy, 1986; Kissileff, Zimmerli, Torres, Devlin, & Walsh, 2008; Legoff & Spigelman, 1987). Herman and Polivy (1990) successfully demonstrated that individuals who are primed with food cues prior to a measure of ad libitum intake consume a level of calories which exceeds their homeostatic needs. These effects have been replicated in both saited and fasted participants. (Cornell, et al. 1989; Nederkoorn, Smulders, Havermans, & Jansen, 2004). The extent to which food cues generate a specific desire for a consumed food or a more contextual response (generating an increased desire to consume other liked foods) has been explored experimentally (Fedoroff et al 1995; 2001). Fedoroff and colleagues (1995; 2001) exposed restrained and unrestrained eaters to the scent of pizza baking in an oven. Participants' intake of cookies or pizza was then measured; cue exposure was associated with increased intake only for the cued food. Similarly a study by Cornell, Rodin and Weingarten (1989) found that when participants were provided with a choice of food after priming they only consumed more of the food item they had been pre-exposed to. Based on this evidence it has been suggested that exposure to food cues elicits "incentive-induced hunger", this is a motivational state which induces specific food craving (Weingarten, 1989).This supports proposals from animal research that the effects of conditioning cues are specific to the US (Petrovich & Gallagher, 2007; Petrovich et al. 2007).

A more ecological measure of the effects of priming, examines the impact of food advertising on intake. Participants who are exposed to advertisements containing salient food cues increase calorie intake (Halford, Gillespie, Brown, Pontin & Dovey, 2004). Harris, Bargh and Brownell (2009) revealed that children consumed 45% more calories from snack foods after viewing advertisements featuring high calorie snacks. Similarly Halford's et al (2004) found that exposure to food advertisements resulted in higher ad libitum intake, with largest intake of calorie being recorded for the overweight group.

The priming literature also measures how food cues influence anticipatory appetite responses. On a physiological level exposure to food cues can be measured by examining changes in salivation, gastric activity, heart rate and insulin levels, (Johnson & Wildman, 1983; Sahakian, Lean, Robbins, & James, 1981). A study by Temple, Kent, Giacomelli, Paluch, Roemmich, and Epstein (1992) measured salivatory responses in children who were asked to look, smell and think about a cheese burger placed in front of them. This study showed salivation increased in line with the participant's motivation to consume the item in front of them. Alternatively more implicit measures may be employed such as recording changes in reported craving or desired portion size of a cued food (Nederkoorn & Jansen, 2002).

1.5.1 Individual differences in reactivity to food cues

Research has explored factors which underpin individual variability in reactivity to food cues. The extent to which variability is expressed in an individual's behavioural relationship with food remains unclear. For example individuals who are particularly responsive to food cues in the environment may express this sensitivity through increased opportunistic feeding and overeating (i.e. external eating). This notion parallels findings within the addiction literature which demonstrate that drug cues elicit heighted behavioural, emotional and physiological responses in substance users compared to controls (Hill, 2007). Alternatively when an individual is aware of their heightened responsiveness to food stimuli this may result in a conscious attempt to control food intake (i.e. restrained eating) (Papies, Strobe and Arts, 2007)

It is important to note that recent proposals within the addiction literature indicated the existence of a phenotype for cue reactivity. Animals which have an increased propensity to approach food cues in their environment also exhibit elevated reactivity to drug cues (e.g. Uslaner, Acerbo, Jones, & Robinson, 2006, Saunders and Robinson 2011). This evidence has been used to propose the existence of a phenotype which is more susceptible to cue reactivity (or Pavlovian conditioning). Mahler and Wit (2010) have recently published evidence for a cue reactivity phenotype in humans which they suggest can predict elevated sensitivity to conditioned stimuli. This study explored cue induced craving for cigarettes and food stimuli in adult smokers. Participants were shown food or smoking related images after an eighteen hour period of deprivation. Findings revealed that individuals who had higher indices of cue induced craving from smoking cues also displayed the same elevated responses to food cues (Malher & Wit, 2010). The interpretation of increased craving for both food and nicotine reward is that substance users may have a general propensity to respond to conditioned stimuli. Mahler and Whit (2010) propose that future work needs to explore whether this phenotype is present for other combinations of drug and natural rewards. According to Malher and Whit (2010) this "phenotype" may also reflect the tendency to react in response to bottom up motivators of behaviour.

Flagel and colleagues (2010) has explored these hypotheses in the animals. The study examined the extent to which the cue reactivity phenotype is characterised by behavioural and neurobiological traits; rats which had a high or low propensity to self administer drug reward were trained to respond to food cues. High responders learnt to approach the food cue, where as low responders only learnt to approach the location where the food was delivered. Flagel et al. (2010) suggests that this demonstrated that rats that had a cue-reactive phenotype were able to attribute increased incentive salience to the conditioned cue. In line with the predictions outlined above, high responders were show to be more impulsive and displayed higher behavioural disinhibition (as measured by locomotive control). This group were also more reactive to dopamine agonists and had higher numbers of dopamine receptors.

1.5.2 Cue reactivity and body mass index

Indices of food cue reactivity have been found to correlate with occurrences of binge eating (Sobik, Hutchison, & Craighead, 2005) and dieting (Stirling & Yeomans, 2004). As binge eating and "yo-yo" dieting are both in themselves risk factors for obesity; it can be inferred that individuals who engage in these behaviours may do so as a result of underlying sensitivity to food cues. Heightened responsively to food cues can be expressed in a range of different behaviours. For example binge eating may be the result of attentional bias and craving increasing approach behaviours. Likewise engaging in repeated attempts to control bodyweight through dieting may reflect that an individual is awareness of their tendency to overeat in respond to food cues. If these predictions are true it can be hypothesised that elevated cue-reactivity will be reflected in increased body mass index. In support of these claims epidemiological research has demonstrated that the obesogenic environment impact on feeding behaviour is dependent on weight status (Flegal & Troiano, 2000). Flegal and Torino (2000) tracked BMI change in adults and children living in the USA From 1988 to 1994; population data indicated that the greatest increase in weight was found for individuals who were classified as obese at the beginning of the study.

A number of studies have demonstrated that obese participants are more responsive to food cues compared to individuals of normal weight (Epstein et al. 1996; Halford, et al. 2004; Johnson & Wildman, 1983). Comparisons of physiological reactivity to food stimuli between obese and normal weight participants have established that following cue exposure, obese participants release more insulin (Johnson & Wildman, 1983) and have heightened salivatory responses (Epstein et al.1996). In a series of studies by Epstein and colleagues (1996) participants were exposed to the taste of a high calorie yogurt. salivatory responses took longer to decline in obese participants. This delayed decline in anticipatory responses may be interpreted as evidence that obese individuals are motivated to feed for a longer period than individuals of normal body weight (Epstein et al. 1996; Johnson and Wildman, 1983).Obesity was also predictive of highest calorie consumption during a subsequent intake task.

Sobik, Hutchison and Craighead (2005) aimed to establish if cue reactivity was a significant correlate to binge eating and whether binge eating behaviour was underpinned by a genetic phenotype (DRD4 S). This allele has previously been associated with elevate drug craving and dopaminergic function. Food cues elicited highest craving in individuals with the DRD4 s polymorphism; however this reactivity was only found to be a significant correlate of body weight in females (Sobik et al. 2005). The complex relationship between cue-reactivity and susceptibility to weight gain is illustrated further in a study by Tetley, Brunstrom and Griffiths (2009). This examined the relationship between sensitivity to food cues, body mass index and everyday portion size selection in a large sample of female participants (N=120). Participants were primed with the sight and smell of pizza; findings revealed that there were no differences in reported craving or desire to eat in obese and normal weight participants. However individuals who selected greater portion sizes were found to be the most reactive to the food prime. These subsequently increased their reported desired portion size of the cued food (Tetley et al. 2009). It is unclear whether these findings depict that those individual who have the tendency to overeat desire larger portions of cued food, or if desiring large portion of palatable food is an expression of heightened responsively.

The behavioural differences in food cue reactivity between obese and normal weight participants does not seem to be expressed on a neural level. Nijs, Franken and Muris (2008) compared the neuronal response (ERP) to food stimuli in obese and lean participants across both a saited and hungry condition. There were no differences in P3 and LPP amplitudes (ERP components associated with motivation) in obese and normal weight participants. Rather amplitude of ERP components were elevated in response to food items across all participants and positively correlated with reported hunger (Njis et al. 2008).

It could be proposed that the relationship between BMI and cue-reactivity is mediated by the extent to which sensitivity to food cues in the environment is expressed through overeating. Externality theory (Schachter, 1971) proposed that individuals are particularly susceptible to weight gain if they habitually eat in response to external cues. Based on this assumption, cue-reactivity may only be predictive of increased BMI in populations where eating is not driven by homeostatic control. The main psychometric measure of external eating is the DEBQ external food sensitivity (EFS) subscale (Van Strien, Frijters, Bergerand Defares, 1986). A recent publication by Passamonti et al. (2009) produced strong neurological evidence validating the argument that external eaters are more susceptible to food cues in their environment (at least on a neurological level). This study measured fMRI response to hedonic food stimuli in twenty one participants. Results showed that measures of EFS positively correlated with degree of activation in neural reward circuitry.

It must also be considered that the degree to which this vulnerability is expressed through overeating is dependent on a range of other psychosocial factors. This may explain why EFS scores do not consistently predict BMI. High EFS scores have been identified as being significantly higher in morbidly obese patients prior to gastric surgery than in normative population (Hörchner, Tuinebreijer & Kelder, 2002). Similarly Rodin and Slochower (1977) found that external responsivity was predictive of weight gain in non obese children. Measures of body weight have not always been found to positively or strongly correlate with high external responsiveness (Conger, Conger, Costanzo, Wright, & Matter, 1980; Price & Grinker, 1973; Rodin & Slochower, 1976; Rodin, et al., 1977). Current research lends support to the idea that it is not external eating per-say that drives overeating, but rather a combination of personality factors which when paired with high external responsively promote overeating For example high scores on the EFS have been shown to correlate with elevated food craving (Burton, Smit, & Lightowler, 2007), impulsivity and lower self discipline (Elfhag & Morey, 2008). These personality factors are also likely to be implicated in overeating. To summarise there is evidence within the literature to substantiate the hypothesis that obese individuals (or those at risk of developing obesity) are hyper responsive to food relevant information. However this sensitivity is only likely to elicit overeating in individuals who have poor behavioural control.

1.5.3 Dietary restraint and cue reactivity

Although the presence of food cues may produce a temptation to overeat; however the decision to eat is mediated by cognitive processes. Choices around meal and snack intake are guided by an individual's cognitions; for example an individual may choose not to purchase a chocolate bar from a vending machine if they know that a large meal will be consumed in only a few hours time. This shows that some individuals are successful at ignoring cues associated with short term reward when they are detrimental to long term goals (Papies, Stroebe, & Aarts, 2008) .

Pappies and colleagues recently demonstrate that the "allure of forbidden food cues" is stronger for restrained eaters. Papies, Strobe and Aarts (2007) devised a paradigm which aimed to demonstrate that food cues subconsciously activate thoughts about palatable foods in restrained eaters. Participants were asked to read behavioural descriptions which contained details about rewarding foods e.g. "Peter is taking a big piece of apple pie". Findings revealed that exposure to food sentences stimulated thoughts about the rewarding nature of food (e.g. "yummy, delicious") only in restrained eaters. In a similar study also run by Papies and Hamstra (2010) exposure to tempting food cues was found to elevate unsuccessful dieters reported "wanting" for high calorie snack foods. Participants were primed with either a tempting or neutral food cues during an online sentence completion task. After priming, participants were required simply to rate their desire to consume a variety of high calorie and low calorie snack foods. Results indicate that the presence of a tempting food prime decreased wanting for high calorie snack food in restrained eaters who were of normal body weight (successful dieters) but increased wanting for these foods in unsuccessful dieters (individuals who were overweight). Both these studies illustrate that mere exposure to food cues is enough to elicit thoughts about the hedonic properties of food (Ouwehand & Papies, 2010). It could also be proposed that such thoughts are driving differences in food cue reactivity; the differences in task performance between individuals of normal body weight and restrained eaters may be a consequence of them experiencing heightened craving and more frequent hedonic thoughts. These may in turn promote hyper vigilance for food information and increase cue reactivity.

It is important to note when interpreting this research that there may be inherent differences in the behaviour of restrained eaters who are dieting to lose weight, and those who are not (Lowe & Timko, 2004). Work by Lowe and Timko

(2004) demonstrated that restrained dieters report higher incidents of "yo-yo" dieting that restrained non dieters. Lowe and colleges (2004) propose that cyclic failed attempts to successfully maintain weight loss indicate underlying defects in regulating eating behaviour. Based on this assumption the degree to which a restrained eater displayed cue-reactivity and attention bias may be dependent on not only their current dieting status but also their dieting history.

Self regulation is clearly important to human feeding behaviour and it is likely that it is these processes mediate the relationship between cue reactivity and intake. In recent years appetite research has began to consider the cognitive and behavioural effects of ignoring food cues in the environment. In particular there has been a focus on the impact that "temptation" has on dieting behaviour (Ouwehand & Papies, 2010; Papies et al. 2007; Papies and Hamstra 2010). Poor self regulatory control over intake is likely to lead to opportunistic or disinhibited eating. Individuals engaged in habitual dieting behaviour exert strict conscious control over calorie intake. Dieters make up a subset of the population who are focused on reducing their calorie intake to reach their long term goal of weight management (Herman & Polivy, 1984, 1990). The research literature often classifies dieters, in regards to their success at long term weight loss. The term restrained eating has become synonymous with individuals who are highly motivated to lose weight but whose attempts of long term weight loss are unsuccessful (Herman & Polivy, 1984). Psychometrically restrained eating can be measured by the Revised Restraint scale (Herman and Polviy, 1980) . The RS measures restriction of calorie intake but also an individual's propensity to overeat. RS has been associated with higher BMI (Klem, Klesges, Bene. & Mellon, 1990; Lowe & Fisher, 1983; Ruderman, 1983; Ruderman & Christensen, 1983). However when used in prospective research the RS does not appear to predict change in body weight (Klesges, Klem, Epkins, & Klesges, 1991; Tiggemann, 1994; Tiggermann, 2004). Current consensus is that the restraint subscale [TFEQ_R] of the three factor eating questionnaire (Stunkard & Messick, 1985) or the restrained eating scale from the Dutch Eating Behaviour Questions [DEBQ_R](Van Strien, 1999) provide the "purest" measures of restrained eating. This is because they allow overeating to be distinguished from restrained eating.

Dieters and in particular restrained eaters are individuals who are likely to have strong motivation to ignore food cues in their environment. This relationship is complex as dieters often display ambivalence (conflicting feelings towards food). The existence of ambivalence can be supported by empirical evidence that links restrictive eating patterns with elevated craving (Cepeda-Benito, Fernandez, & Moreno, 2003) .This indicates that although an individual may be actively avoiding specific foods, they may still consciously desire it. A consequence of the proposed reciprocal relationship between craving and attentional bias is that food information may gain increased saliency for dieters (Field and Cox, 2008).

There is a wealth of literature examining the cue reactivity in restrained eaters. Herman and Polivy (1990) proposed that any behavioural differences found between obese and non obese participants in priming experiments can actually be attributed to the fact that most obese participants are restrained eaters. Their series of research studies clearly outlined that individuals with high levels of dietary restraint have elevated appetite responses when primed with food cues (Herman and Polivy, 1990). An early study by Hischer and Herman (1977) found that the number of calories consumed by obese participants following a preload was related to dieting status and not obesity. Retrained eaters reliably display the strongest anticipatory reactions to cue exposure when compared to individuals low on dietary restraint (Fedoroff et al. 1997; Overduin, Jansen, A., & Eilkes, 1997) . Correspondingly food cues have a pronounced effect on calorie intake in individuals with high dietary restraint (Nederkoorn & Jansen, 2002). A recent study by Fedroff, Polivy and Herman (2003) examined food related thoughts and subsequent food intake in restrained eaters following consumption of a food prime. Restrained eaters were found to have significantly higher food intake but also reported more food related thoughts than unrestrained eaters. Interestingly participants who scored low on measures of dietary restraint were the group which displayed highest anticipatory responses after exposure to food cues (Fedroff, Polviy and Herman, 2003). The differences in intake seen in this experiment may be explained by the fact that individuals who score low on dietary restraint are more effective at suppressing food cravings generated by anticipatory responses.

The research outlined in the previous section clearly demonstrates that restrained eaters show elevated responsively to food cues (Fedoroff, Polivy and Herman. 1997) and often overeat in their presence. Such findings have been interpreted as evidence that restrained eaters find it difficult to ignore food stimuli. This difficulty is thought to arise because the hedonic qualities associated with desired foods are more potent for habitual overeaters, thus when even when dieting this desire is able to override long term dieting goals (Pappies, 2008). It is possible that restrained eaters are a sub group, who have poor top down control of their feeding behaviour. Pappies, Strobe and Aarts (2007) consider the difference between successful and unsuccessful dieting to be attributed to underlying cognitive mechanisms. The presence of a desired food cue in a restrained eater's environment generates hedonic thoughts about food, the result of which is the experience of ambilivance. Papies et al. (2007) considered that what differentiates successful and successful dieters is that successful dieters recognise these hedonic thoughts and use them to trigger cognitions centred on their dieting goals. This in essence enables them to self regulate their behaviour and subsequently not be motivated to consume the desired food. However in unsuccessful dieters' hedonic thoughts elicited a strong motivation to overeat which they find difficult to override and thus results in an episode of overeating (Papies, et al 2007).

1.5.4 Summary

The previous section established that there is considerable evidence demonstrating that exposure to food cues generates reliable physiological responses, elevated appetite and increased intake. It appears that there may exist a number of sub groups that display heighted reactivity to the presence of food cues (i.e. obese participants, restrained eaters and external eaters). Although there is considerable evidence that these groups exhibit increased appetite responses during priming manipulations, this behavioural evidence could be viewed as simply anecdotal. As the majority of the previously reviewed studies are based on correlations rather than cause and effect.

To strengthen the proposed argument that the effects demonstrated in the priming literature are indeed representative of individual differences in cue reactivity; research has began to explore the attentional processes underpinning our relationship with food cues. If food cues are more salient for individuals who are susceptible to weight gain, it can be subsequently predicted that such these individuals will display behavioural biases when processing food cues. Subsequently in recent years overeating has been viewed as analogous to pharmacological addiction. Foods like misused substances are high in hedonic value and much like a drug addict individuals who habitually overeat often report craving for hedonic foods. This parallel with addiction has led to the proposal that obese individuals much like conventional addicts may display hyper responsiveness to food related cues. To put simply, food relevant information is likely to "grab attention "and elicit an approach response more frequently in obese individuals than in those of normal body weight.

The addiction literature has shown that drug cues "grab attention" and elicit automatic approach responses in habitual drug users. Subsequently, attentional biases for drug-relevant information have been consistently identified in smokers, drug users and alcoholics (Bauer & Cox, 1998; Cox, Hogan, Kristian, & Race, 2002; Gross, Jarvik, & Rosenblatt, 1993; Lubman, Allen, Peters, & Deakin, 2007, 2008; Lubman et al., 2009; Stormark, Laberg, Nordby, & Hugdahl, 2000; Warthen & Tiffany, 2009; Waters et al. 2007; Waters & Feyerabend, 2000). It is predicted that attentional bias plays a functional role in maintaining addictions; correspondingly a number of publications have demonstrated that drug users who have elevated attentional biases have poorer treatment outcomes (Cox, et al., 2002; Marissen et al., 2006; Waters et al., 2003, 2004). The appetite literature has begun to explore the extent to which individuals who overeat also display processing biases for food cues. This literature will be reviewed in more depth in section 4.1 (Chapter 4).

1. 6 Neural processing of food cues

In recent years advances in human neuroimaging has lead to a number of publications investigating the neuronal structures implicated in feeding behaviour. Appetite control is attributed to two main neural systems which are homeostatic and non homeostatic in basis. The homeostatic system is implicated mainly in the instigation of feeding and consists of the orbitorfronal context, insular, hypothalamus, striatum and the amygdale. A second network within this system is related to the cessation of feeding, and implicates regions located within the prefrontal cortex. Traditionally obesity epidemiology was subscribed to deficits in homeostatic control or attributed to "flawed" interpretation of appetite sensations (Rolls, 2007). However control of appetite is no longer considered to be a function of homeostasis alone. Although the metabolic brain is undoubtedly efficient at managing calorie intake and energy expenditure; there remain contexts in which human feeding continues despite the presence of metabolic cues signalling the cessation of intake. Such behaviour is often considered to be consequential of changes in modern lifestyle; hedonic food products are in abundance in the western world and therefore social environments often encourage prolonged eating or drinking for "pleasure". Similarly for many individuals it may not be possible to feed immediately after experiencing hunger and instead calorie intake is restricted to "meal times". Therefore it can be extrapolated that although appetite sensations (or homeostasis) may once have directly driven feeding this may not necessarily be the case in the modern food environment. Therefore viewing obesity's epidemiology as a sole function of inadequate metabolic control is considered derisory. Cognition is fundamental to the processing of food related information (i.e. identifying food availability, food choice and processing food reward) (Berthoud, 2009) thus appetite control is now considered to be more dualistic.

As a consequence research has begun to focus on the role which the non homeostatic system plays in feeding behaviour; this system controls processes associated with reward and motivation. The rewarding nature of food can be considered as being one of the most compelling motivators of modern feeding (Kringlebach & Berridge, 2009). The discovery of the brains "pleasure centre" in the 1950's (Olds and Milner, 1954) has led to the extensive mapping of the reward system. All natural rewards (food, sex) share the same common neural substrates (Kringlebach & Berridge, 2010). Within the neurophysiology literature the nucleus accumbens, ventral palladium, brainstem and cortical structures as considered to be central to the processing of food reward. Pharmacological stimulation of this network in rodents directly increases the intake of foods which are high in fat and sugar. This effect has also been replicated in saited animals (Beaver et al. 2006). There is substantial evidence that the areas implicated in food reward overlap with those which process drug reward (Kelley & Berridge, 2002).

There is strong neurological support for the proposal that food cues are more salient when an individual is hungry (Cornier, et al 2007; Small, Zatorre, Dagher, Evans & Jones-Gotman, 2001). Small et al (2001) used PET to explore changes in brain activity in "chocoholics" during feeding. Hungry participants were asked to consume chocolate until they reached a point past satiation. At the start of chocolate consumption increased activation was found in the orbitorfronal cortex and insular, this activation also correlated with rated pleasure. Satiation was associated with reduced activation in these regions and also decreased reports of pleasantness. Correspondingly findings from a neuroimaging study conducted by Hinton et al.

(2004) showed that fasting is associated with increases activation in the ventral stratum, amygdale, and anterior insula along with the medial and orbitorfronal cortex.

An alternative methodology is to compare how the brain responds to food stimuli and neutral stimuli. If food stimuli are associated with heightened reward value, this saliency would subsequently be reflected in increased activation within reward circuitry. Nijs et al. (2008) compared the electrophysiological response to food stimuli and neutral stimuli by measuring event related potentials (ERP). Food stimuli were associated with increased amplitude in ERP components (P3 and Late Positive Potential LPP) which have previously been associated with processing of motivationally salient information. Elevated amplitude of P3 and LLP is considered to reflect an increase in cognitive resources engaged in process salient stimuli (Kork 1997 as cited by Nijs, et al., 2008). This increased cerebral activity, is similar to that found in the addiction literature. Herrmann et al. (2000) compared evoked P3 components elicited by alcohol stimuli in alcohol dependant participants and control participants. Peak amplitude of P3 was significantly higher in response to alcohol stimuli in alcohol dependent participants. Establishing differences in evoked brain responses to motivationally salient cues provides further support that the behavioural effects of cue reactivity and attentional bias are underlined by automatic processes.

Findings gained from fMRI further demonstrate that degree of activation elicited within neuronal circuitry to food stimuli is dependent on reward value (Cornier et al. 2007, Pelchat et al. 2004, Small et al. 2001). Cornier, Von Kaenel, S., Bessesen, & Tregellas (2007) presented food images which had previously been rated as being highly palatable or neutral to participants during fMRI. Increased activation was found in response to hedonic cues compared to those which had been neutrally rated (Cornier, et al. 2007). Reduced activity in reward circuitry was seen when participants had been fed to satiation (Cornier et al. 2007). Similarly Pelchat, Johnson, Chan, Valdez, & Ragland (2004) asked participants to imagine the sensory properties of a highly desired food whilst recording fMRI. Reported craving was directly associated with increased activation in the hippocampus, insula and caudate (Pelchat et al. 2004). Affect appears to be an additional mediator of the neuronal response to food cues. Kilgore and Yurgelun-Todd (2006) manipulated participant mood prior to them being shown images of high calorie and low calorie foods during an fMRI scan. When participants were in a positive mood and shown high calorie items there was decreased activation found in regions associated with satiety such as the orbitorfronal cortex. Conversely in response to low calorie food there was increased activation in the medial orbitorfronal and insular cortex. The negative mood manipulation elicited the opposite pattern of neuronal activity, high calorie food cues were found to generate greater activations in regions associated with the initiation of feeding, while low calorie foods increased activity in the orbitorfronal cortex (Killgore & Yurgelun-Todd, 2006). Interpretation of the patterns of activation observed by Small et al (2001) and Kilgore and Yurgelun-Todd (2006) predicts that there is segregation of the motivational systems in regards to approach and avoidance behaviour.

An additional focus of the neurobiology of appetite is the role of dopamine in eating behaviour; the dopaminergic system is central to many theoretical accounts of cue salience and attentional bias. During feeding, dopamine (a neuro chemical which is implicated in reward reinforcement) is released into the dorsal striatum. This has been demonstrated by Small et al. (2001) who compared PET scans after participants had fasted for 16 hours or consumed a favourite meal (after fasting). This study found that the amount of dopamine released into this region correlated with the perceived pleasure gained from eating (Small et al. 2001). These findings support the proposition that dopamine mediates the hedonic aspects of pleasure associated with a hedonic stimulus (Small et al. 2001). Berridge (2009) proposes that these neural systems work dynamically to generate the experience of pleasure, and subsequently coined the phrase "pleasure gloss" to describe the ability of the brain to generate a "liking" reaction to a specific substance or food. Hedonic hotspot found in the posterior half of ventral palladium and medical shell of the nucleus accumbens is central to establishing this "pleasure gloss". When these hotspots are stimulated with dopaminergic neurotransmitters such as GABA-Benzodiapine and Opiod Endocannabinoid both human and animal participants display enhanced liking reactions for sweet tastes (Smith & Ferguson, 2008).

1.6.1 Individual variation in the neural processing of food cues

The brain has evolved to differentiate processing of food cues based on their reward value. From this it can be hypothesised that the behavioural associations drawn between overeating and biased processing of food stimuli may also have a neural basis. Support for these claims can be seen in a study by Burger and Stice

(2011) which proposes that the propensity to overeat may be underpinned by heighted neural responsivity to reward. The degree of activation within the orbitorfronal and prefrontal cortex following consumption of a high calorie milkshake was found to directly correlate with self reported dietary restraint (Burger and Stice, 2011). This is a behavioural trait associated with increased reactivity to food cues and elevated BMI. An easy extrapolation to make from this literature would be that individuals who have higher body weight are driven to overeat due to dysfunction within the systems which control non homeostatic feeding. Stice, Spoor, Bohon, Veldhuizen & Small (2008) produced further evidence to support the claims that obesity is associated with increased activation within this system; neural activity within the reward circuits of obese and lean participant were compared in response to a hedonic food stimulus. Exposure was associated with greater activation in regions associated with reward processing in obese participants compared to those of normal body weight. This effect was replicated when participants were asked to consume a portion of the hedonic food. Decreased activation in the caudate nucleus (area of the striatum) was found only in the obese participants sample during consumption.

In regards to dopamine, both human and animal research studies have demonstrated that obesity is associated with decreased numbers of dopamine receptors (D2) in the stratum (Volkow, Wang, Fowler, & Telang, 2008; Wang et al., 2001). This has lead to the "anhedonia hypothesis" which postulates that the addicting substances have a detrimental impact on neural circuitry associated with reward (Wise, 1996). Comparison of activation in the striatum in normal weight and obese participant illustrated that obese participants had significant lower activation in areas associated with the release of dopamine when shown palatable food stimuli (Stice et al, 2008). However it is important to note that a number of publications have produced data signalling the opposite trend. Work by Rothermund et al (2007) and Soeckel et al. (2000) found that obese participants had greater activation in the striatum in response to food images

The extent to which overeating is a result of a lower signal capacity within reward circuitry remains unclear (Stice et al. 2008).This concept proposes that individuals experiencing such dysfunction would need to consume higher amounts of rewarding foods to experience the equivalent degree of reward as an individual with normative reward circuits(Wang et al. 2001) . In 1991, Noble et al (1991) identified an alle (A1 tagIA) which is associated with lowered dopamine receptors in the striatum and reduced activation to visual food stimuli. Individuals with this alle were found to have reduced resting metabolism (Noble et al. 1991) and be vulnerable to long term weight gain. However lower prevalence of dopamine receptors may be also be a directly caused by overeating. Work by Colantuoni et al. (2001; 2002) has found that regular consumption of foods with high fat and sugar content results is associated with decreased sensitivity of D2 receptors in rodents. These effects have been replicated within the animal literature (Bello, Lucas and Hajnal. 2002; Kelley. Will. Steininger. Zhang and Haber. 2003). Similarly Stice, Yokuum, Blum and Bohon (2010) conducted a prospective study on dopamine activity in overweight and obese participants. This demonstrated that individuals who gained weight over the six month period had reduced striatal activity in response to palatable foods. However as the participants recruited by Stice et al (2010) were overweight at baseline the true cause of reduced activity remains debatable.

1. 6.2 Reward sensitivity

Variability in neural sensitivity to food reward can also be detected at a purely behavioural level: Individuals scores on a commonly used measure of trait reward sensitivity (Behavioural Activation Scale [BAS], Carver and White, 1994) positively correlate with reported food craving, hyperphagia and body mass index (Davies et al. 2004, Dawe & Loxton, 2004; Franken & Muris, 2005). Beaver et al. (2006) has also produced empirical evidence that high BAS scores correlated with elevated neural responses to hedonic food stimuli. Beaver et al. (2006) collected fMRI data from fourteen participants who were shown food stimuli of varying hedonic values. Results showed that foods high in hedonic value elicited increased activation in neural reward network, and this activation strongly correlated with BAS measures. These behavioural findings are comparable to the neurobiological literature which proposes that differences within reward circuitry may predict overeating. However it is important to note that individuals who had high BAS scores did not perceive the food items to be any more pleasant than those with lower scores

Further support to claims that impulsivity may be an important mediator of overeating can be seen in an experiment by Guerrieri. Nederkoorn, Schrooten, Martijn & Jansen (2009).This study cognitively primed participants to act either impulsively or to inhibit their behaviour prior to measuring calorie intake.

Manipulating impulsivity was associated with increased calorie intake. The strongest effects were for individuals who scored highly on dietary restraint, whilst priming had the opposite effect on current successful dieters and was associated with decreased calorie intake (Guerrieri et al. 2009).

A number of experiments have explored the role of reward sensitivity in the development of obesity. Comparisons of subjective ratings made by obese and lean participants of foods which are high in fat and or sugar consistently reflect that obese individuals rate these foods to be more pleasurable (, Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992; Elfhag & Erlanson-Albertsson, 2006; Wardle, Guthrie. Sanderson, Birch, & Plomin, 2001). Interestingly Wardle et al. (2001) found that children from overweight families provided higher ratings of preference for hedonic foods compared to children from lean families. Correspondingly self reported preferences for sweet tastes have been associated with increased incidences of childhood obesity (Sharam and Hedge, 2009) Rissanen et al (2002) compared the dietary choice of monozygotic twins who had different weight status (one twin was overweight and the other was of normal BMI). The obese twin reported a higher consumption of fatty foods in early adulthood (high hedonic value) and also reported higher incidences of overeating (Rissanen et al. 2002). Behavioural differences are not replicated in studies which require participants to taste and rate hedonic foods. For example, Salens and Epstein (1996) found no differences in rated pleasantness of hedonic foods between obese and lean participants, but did find differences in regards to how reinforcing the food reward was perceived to be. This study found that obese participants if given the choice between consuming a snack food that was high in reward and engaging in a sedentary activity (i.e. computer game) preferred to gain food reward. It is unclear whether a preference for energy dense foods is universal characteristic of obesity. Hill, Wardle and Cooke (2009) compared children's reported liking of a variety of foods. There were no significant associations found between reported preference and future weight gain. Much of the supportive evidence outlined above is based on correlation which makes it difficult to establish if elevated liking is a cause or a consequence of obesity.

The concept that individuals may choose to consume food purely on the basis of its reward value may not be that far from reality. It can be suggested that one of the main impetus for food consumption and food choice in modern day society, is not based on calorie intake but is instead related to the pleasure that will be obtained from foods consumption (Lowe and Butryn, 2007). Such a notion could explain situations where people consume food when they are not physiologically hungry. Lowe and Butryn (2007) has coined the phrase hedonic hunger to describe this new phenomenon. Like all aspects of appetite differences are likely to exist to the extent to which individuals experience hedonic hunger. Much like addicts of illicit substances, it may be proposed that there are subsets of modern society that are compulsively driven to obtain the hedonic pleasure which they associate with consuming highly palatable foods. It is probably that individuals who consistently experience "hedonic hunger" find being in the presence of highly palatable foods a constant temptation. If such individuals consistently give into temptation and consume desired foods, they would be much likely have higher body weight. However hedonic hunger may also be expressed in a more paradoxical manner, individuals who are aware that their desire for food heavily influences their eating behaviour may endeavour to restrict their dietary intake in an attempt to retain a healthy body weight (Lowe & Butryn, 2007). In an attempt to produce an accurate measurement of hedonic hunger the power of food scale (PFS) was developed (Lowe et al. 2009). This measures individual differences in appetite responsiveness (i.e. hedonic hunger) on a 5-point Likert scale (1 don't agree at all to 5 strongly agree) and contains 21 items which assess the effect of the presence of food on peoples thoughts

1.7 General Summary

This review has explored how attending to food cues in the environment may influence overeating. Paying increased attention to food cues compared to neutral cues is considered by many researchers to be a normative processes that motivates feeding when hungry (Cornier et al. 2004; Hinton et al. 2004; Mogg et al. 1998; Small et al.2001; Tapper et al. 2010). Correspondingly there is considerable behavioural and neurophysiological evidence indicating that cues associated with high energy density are the most salient (Cornier et al. 2004, Nijs et al. 2008, Tapper et al. 2010). This is likely to reflect the competitive feeding environment of our evolutionally past; during which quick detection of foods that had a high calorie content was advantageous to survival. The innate propensity to respond and attend to energy dense food cues has implications for obesity risk. However within the modern food environment food cues are abundant and this is likely to present a challenge to individuals who are attempting to loose or maintain their body weight.

The aim of this thesis is to examine the extent to which behavioural differences in attention equate to an increased propensity to overeat. This literature review provides considerable support for claims that individuals who are at risk of developing obesity are more responsive to the presence of food cues. The literature shows that this may be expressed through processing bias (Caltri et al. 2010; Brignell et al. 2009; Hepworth et al. 2010; Newman et al. 2008; Tapper et al. 2008) enhanced cue reactivity (Epstein et al. 1996; Fedroff et al. 1997, 2003; Johnson and Wildman et al. 1983; Mahler and Whit, 2010; Sobik et al 2005, Stirling and Yeomans 2004), increased neural responsivity (Nijs et al. 2008; Stice et al. 2008) or heightened craving and desire to eat (Papies et al. 2010). These findings parallel the addiction literature which theorises that attentional bias; cue reactivity and craving are all features which maintain substance use (Field and Cox, 2008).

The extent to which heightened reactivity to food cues is expressed through overeating appears to be dependent on a number of factors. For the purpose of this thesis these factors have been classified into two general themes; "top down processes" are those which are mediated by the prefrontal cortex and can be considered as reflecting cognitive control. Whereas the term "bottom up" processes is used to describe learnt and emotional responses which are likely to be controlled by limbic structures (e.g. amgydala, hippocampal formations and hypothalamus). This literature review indicates that the degree to which attentional bias motivates an individual to overeat is dependent on individual differences in these processes. For example work by Papies and colleagues (2007, 2010) suggests that when exposed to food cues successful dieters displayed decreased wanting and craving for high calorie foods . However exposure to the same cues had the opposite effect for unsuccessful dieters. The ability to successfully maintain a diet can be considered characteristic of an individual who is able to exert strong top down control over their feeding behaviour. The extent to which these "cognitive coping mechanisms" develop as a consequence of a history of food intake being driven by "bottom up" processes such as reward responsivity remains unclear. Correspondingly it could be predicted that individuals who exhibit poor top down control (e.g. high disinhibition, external eaters, and emotional eaters, impulsivity) may display greater responsivity to food cues which consequently increases their propensity to overeat. Behavioural support for this prediction can be seen in the attentional bias literature (Brignell et al

2009; Hepworth et al. 2010; Hou et al. 2010; Newman et al. 2008) (For review see Section 4.1)

1. 8 Aims and Predictions

The aim of the thesis is to explore the extent to which behavioural indices of attentional bias to food cues correspond to individual differences in eating behaviour. A main focus of this work is to address if individuals who are hyper responsive to the presence of food cues in the environment have increased susceptibility to weight gain. Additionally this thesis wished to explore how food cue in the environment acquire salience, capture attention and influence appetite.

The first experiment in this thesis (Chapter 3) will explore the interplay between the pull of food cues in the environment, reward sensitivity and overeating. It is predicted that eating behaviours associated with increased cognitive control (e.g. dietary restraint, low behavioural impulsivity) will be associated with lower body weight. Whereas it is predicted that behaviours associated with lowered cognitive control (e.g. disinhibition, external eating) will predict higher body weight. Equally the degree to which bottom up mechanisms (reward responsivity, pull of food cues) influence weight status will be explored.

Experiment 2 (Chapter 4) aims to follow up these findings by exploring how variability in behaviours associated with self regulation are reflected in attentional bias to food stimuli. It is predicted that individuals who are highly responsive to the presence of food cues will have diminished top down control. This experiment will specifically explore the impact of disinhibition and priming on attentional bias. If the literatures predictions that being high responsively to food cues motivates individuals to overeat are justified, this study should also find correlations between body weight and measures of attentional bias. The impetus of Experiment 3 is to establish how manipulating attention to food cues influences food intake. It is predicted that individuals who are trained to increase attention to food cues will report elevated craving and have higher ad libitum calorie intake. It is anticipated self regulatory behaviours such as dietary restraint may mediate the extent to which attentional biases is expressed in overeating.

The focus of Chapter 5 is to explore how food cues in the environment acquire salience. This chapter focuses on the role of associative learning in the development of cue saliency. The experiments in this chapter will train participants to associate novel cues with differential rates of hedonic reward. If incentive value of a cue is related to attentional bias it is predicted that greater attentional resources will be allocated to cues which were paired with reward during training. This may be represented behaviourally as difficulty disengaging from rewarding cues (Experiment 4 and 5) or through cue elicited craving (Experiment 6). The novel experimental design used in this chapter also aims to address methodological issues which were raised in Chapter 4 in regards to current measures of attention. An additional aim of this chapter is to establish if electrophysiological techniques can identify neural correlates of cue saliency

Chapter 2

Methods and Procedures

Chapter 2: Methods and Procedures

2.1 Participants

Participants for all studies were drawn from the staff and students population at Swansea University. Male and female participants were used in all experiments. Studies were publicised through university wide email and posters. Student recruitment within the Psychology Department was carried out using the Departmental Experimental Management System [Sona Systems, Tallinn, Estonia]. All advertisement clearly stated that the research studies advertised would be exploring appetite; however the true nature of experiments was not explicitly stated. In order to minimise demand characteristics the studies were advertised more generally e.g. "experiment into the effect of food images on mood". Although the full nature of the research was disclosed during debrief; the procedural information which was provided to participants at the start of the experiment was consistent with the cover story that the researcher was measuring mood, and therefore did not provide specific detail about what the tasks were measuring or what the experimental aims were. Testing for all studies took part during the hours of 1pm and 5 pm.; unless otherwise stated in the specific method sections participants were asked to consume their usual meals prior to the testing session but to fast during the preceding hour. As Experiments 2 and 3 shared similar protocols only naive participants were allowed to take part in these experiments. This was also the case for Experiments 4, 5 and 6; therefore if participants had taken part in one of these experiments there were no longer eligible to participate in other studies run by the experimenter.

2.1.1 Pre Study Screening

For all experiments participants were required to complete an online screening questionnaire to ascertain their suitability. The structure of these questionnaires differed depending on the nature of the experiment, but all contained TFEQ measures. These questionnaires were hosted on www. surveymonkey.com. [Portland Oregon, USA]. Participant recruitment adhered to the following selection criteria:

- Participants were non vegan or vegetarian
- Individuals who had a clinical history of disordered eating were excluded from the study.

- Dieters were excluded.
- Participants could not currently taking any prescribed medication (asides from the contraceptive pill)
- Participants with diabetes or any known food allergies/intolerances were not permitted to take part in any experiments that involved the consumption of food (Experiments, 2,3,4,5 and 6).
- Due to the nature of CS used in the Experiments 4,5 and 6 fluent mandarin speakers were excluded
- Participants taking part in experiments which required recording of EEG (Experiments 4, 5 and 6) were informed that they were not allowed to consume any alcohol after 11:00pm the night before the testing session. Use of recreational drugs for the 24 hours prior to testing was also not permitted.

2.2 Ethics

The protocols for each study were approved by the Department of Psychology Research Committee and were subject to risk assessment. All experiments were designed in adherence to the British Psychological Society's guidelines for conducting research (BPS Code of Ethical Conduct, 2009). Written consent was obtained from each participant prior to the start of each experiment (Appendix F). Immediately before each study participants were provided with an information sheet and consent form to read through and sign. These forms disclosed details regarding the study protocol, checked again whether the participant fitted recruitment criteria and outlined ethical information such as right to withdraw without penalty and confidentiality. Similarly on completion of all experiments, participants received a debrief form which disclosed the true nature of the study.

2.3 Participant Payment

All respondents to the survey used in the first experiment were entered into a prize draw from which one participant won a £20 high street voucher. All participants in Experiment 2 received course credits for their participation. Participants in Experiment 3 had the option to received £5 payment or course credits. Participants who had EEG recorded (Experiments 4, 5, 6) were reimbursed £20 for their time in the EEG laboratory. Behavioural participants (those who did not provide EEG recording) in these experiments were offered the choice of £5 payment or course credits. Experiments 4, 5 and 6 were funded by the Wales Institute of Cognitive Neuroscience (WICN).

2.4 Study Location

Experiments 2 and 3 were conducted in the social laboratory in Swansea University. This is a purpose built laboratory which has a separate kitchen facility attached to the testing area. Experiment 4, 5 and 6 were conducted in the EEG laboratory in Swansea University. The testing cubical in this room is located within a faraday chamber which serves to reduce electrical interference and noise.

2.5 Materials

Table 2.1 outlines the methods used for each of the experiments included in this thesis. All questionnaire measures can be found in the appendix.

Table: 2.1:

Measure	Procedure	Experiments 1	2	3	4	5	6
Pre Study Screening	TFEQ		X		X	X	X
	Chocolate Intake				X	X	X
	Alcohol Intake						X
VAS	Food Rating Scale		X		X	X	X
	Desire to Eat		X	X	X	X	X
	Mood		X	X	X	X	X
Questionnaires	DEBQ	X	X	X	X	X	X
	TFEQ	X		X			
	PFS	X	X				
	BIS/BAS	X					
	BMI	X	X	X	X	X	X
Tasks	AB Task				X	X	
	VDP		X	X			
	Taste Test			X			
	Cue Conditioning				X	X	X
	Cued Craving						X

Tabulated form of methods used in this thesis

2.5.1 Questionnaire Measures of Eating Style

Three Factor Eating Questionnaires [TFEQ] (Stunkard & Messick, 1985) is made up of three subscales which measure cognitive restraint, disinhibition and hunger (Appendix A). The questionnaire contains 36 items requiring a yes-no answer format, 14 items which use a 1 ± 4 response scale and 1 vertical rating. The measure of cognitive restraint (TFEQ-R) contains 21 items. A high score on TFEQ-R reflects an individual's tendency to control food intake in order to maintain a specific body shape/weight. Disinhibition (TFEQ-D) is measured by 16 items; a high score on this scale represents a tendency to lose control over eating. This subscale was used to formulate high or low disinhibition groups in Experiment 2. Finally the hunger scale

(TFEQ-H) measures subjective feelings of hunger; this scale is made up of 14 items. The TFEQ subscales have been shown to have high internal reliability in non clinical sample of adults with a wide weight range (Cronbachs α >0.7) (Karlsson, Persson, Sjöström, & Sullivan, 2000) The TFEQ has high test retest reliability (all scales >0.7) over a 12 month period which suggest that the trait eating patterns measured by the TFEQ are stable (Bond, McDowell, & Wilkinson, 2001).

The Dutch Eating Behaviour Questionnaire (DEBQ) (Van Strien et at, 1986) was used to provide measurement of external eating, emotional eating and restrained eating (Appendix B). Participants respond to items on the DEBQ using a 4-point Likert scale and contains 33 items. The three subscales respectively contain 10 items (external eating and restrained eating) and 13 items (emotional eating). (Van Strien et al. 1986). High scores on each of these measures are considered to reflect a tendency to engage in that trait eating style. The DEBQ has high reported internal consistency and factorial validity (Viana, Sinde, & Saxton, 2008). Bozan, Bas and Asci (2011) showed that the DEBQ had high test retest reliability over a one month period (>0.90). Although the DEBQ_R measures similar constructs to the TFEQ_R (Van Strien et al. 1986) the literature suggest that the TFEQ_R and DEBQ_R measures of restraint should not be used interchangeably.

The Power of Food Scale [PFS] (Lowe et al., 2009) is a recently developed measure of individual differences in motivational appetite pull of the food environment (Appendix D) It has been used in a number of recent studies (Cappelleri, Bushmanki, Gerber, Leidy, Sexton, Karlsson and Lowe, 2009; Ely, Butryn , Stice and Lowe, 2010). The scale was developed to determine the degree to which eating behaviour is driven by hedonic properties of food. The questionnaire can be broken down into three subscales (7 items each) which make assessment of the pull of food over three levels of food proximity – (1) when food is readily available but not physically present, (2) when food is present but not tasted and (3) when food is tasted but not consumed. Each subscale of consists of a total of 21 items which are rated using a 1±5 response scale (where 1= I do not agree and 5 = I strongly agree) -. A high score on each subscale reflects an individual who is highly reactive to hedonic cues in their food environment. The PFS was designed to provide a trait measure of hedonic hunger; this is defined as individual differences in responsivity to the pull of hedonic food cues in the environment. The PFS has high test-retest reliability over a four month period (0.79) (Lowe & Butryn, 2007). Each subscale has been shown to have high internal reliability in both clinical and non clinical samples (Cronbachs α >0.8) (Cappelleri et al. 2009).

The *BIS/BAS* scales (Carver and White, 1994) was used in Experiments 1 and 2 . This measure compares individual sensitivity in behavioural approach system (BAS) and behavioural inhibition system (BIS) (Appendix C). The measure uses a 1±4 response scale (1 disagree strongly to 4 agree strongly). BAS scores are considered to be reflective of individual differences in anticipating pleasure and reward seeking behaviour; The BIS/ BAS scale subsequently measures three BAS components (BAS Drive [4 items]) BAS fun seeking [4 items] and BAS reward responsiveness [5 items]). BIS scores reflect an individual's ability to suppress behaviour that is likely to have negative consequences. The BIS scale has 7 items; a high score on this scale reflects a difficulty in suppressing behaviour. When used in an undergraduate population the BIS/BAS scale has fairly high internal reliability (Cronbachs α > 0.6) (Carver and White, 1994). Only the measure of reward responsiveness and ability to suppress behaviour were considered relevant to this thesis.

2.5.2 Baseline Measures

During each experiment participants were required to complete a number of visual analogue scales which were used to provide standard baseline measure of appetite. In experiments where participants were asked to consume a food item (Experiments 2, 3, 4, 5, and 6) additional ratings of pleasantness were required. These VAS scales are outlined in detail below (a copy of each scale can be found in the Appendix). A mood questionnaire was specifically designed which incorporated a measure of current hunger and thirst under the overall guise of measuring general mood (Appendix G) This questionnaire was also consistent with the cover story given at the start of the experiments which is that the researcher was interested in the effects of food stimuli on mood. The mood questionnaire contained 8 visual analogue scales which rated a number of different aspects of mood (e.g. confidence, anxiety, hunger, thirst) on a scale of 0 (not at all) to 100 mm(extremely high). A high score on this scale would depict that the participant was physiologically hungry while a low score indicates satiation.

Experiments 4 and 5 required a subset of participants to refrain from eating any chocolate products for a 48 hour period prior to testing. This protocol is similar to what was used to explore the effects of exposure to forbidden food items (Stirling and Yeomans, 2004). Participants were required to complete a "general mood questionnaire"(Appendix G) at 8 time points during this 48 hour period. These time points were after evening meal (about 7pm), before bed (about 11pm), after breakfast (10am) and after lunch (2pm). The questionnaire was designed to assess chocolate craving and provide a measure of baseline hunger. It contained 4 mood statements which were rated on a 100 mm unmarked horizontal line scale anchored with not at all and extremely. These statements were "*How hungry do you feel? How much are you missing eating chocolate?, how much are you thinking about chocolate? And how difficult is it to resist eating chocolate?*" The control group in experiments 4 and 5 also completed mood ratings during the 48 hour prior to testing. Again these were competed at the same time points as the chocolate deprivation group. The control questionnaire also contained 4 mood statements which were rated on a 100mm unmarked horizontal line scale anchored with not at all and extremely. These statements asked participants how hungry, relaxed; friendly and clear headed they felt.

2.5.3 Ratings of food pleasantness and sensory properties

For the experiments which taste tests were used (Experiment 3) or used chocolate as CS or prime (Experiments 2, 4, 5, 6) participants were required to complete a food preference questionnaire. This questionnaire was used to ensure that participants focused their attention on the food item they were asked to taste, but additionally provided a measurement of pleasantness and perceived sensory properties (Appendix I). The format of these questionnaires remained consistent across all experiments; participants were asked to rate consumed foods items on four attributes using a 0-100 visual rating scale. Examples of these attributes were pleasantness, crunchiness, richness, sweetness. The main attribute of interest for research purposes was pleasantness; this was used as a measure of how much the food was explicitly liked. Participants were also required to indicate their desire to consume more of the food; again this was done using a 0-100 mm visual rating scale.

2.6 Disguised Taste Test

In Experiment 3 participants were asked to complete a disguised taste test which was used to measure food intake. Participants were taken into the kitchen area of the social laboratory and were seated at a table which contained two plates of food. Two foods were used in the ad libitum taste task these were chocolate buttons and mini chocolate chip cookies. Participants were presented with 70 grams of chocolate buttons; this serving contained 1549.1 Kj (369.996 calories) and 22.05 grams of fat. Similarly the 70 gram portion of mini chocolate cookies contained 1491 kJ (356.12 calories) and 16.73 grams of fat. Participants were told a cover story that the researcher wished to know which item tasted the most pleasant. In line with this cover story participants were asked to consume as much or as little of the foods as they wished, whilst filling out food preference questionnaires. This required them to rate the foods (using a visual rating scale from 0-100) on a number of attributes which included pleasantness, crunchiness and richness. (Appendix I) When the participant had left the laboratory the researcher weighed the remaining food using an electronic food scale.

2.7 Priming

In Experiment 2 participants completed priming manipulation. The food prime was a miniature Cadbury dairy milk bar. Each bar contained 55 kcal and 3.2 grams of fat. When consuming the prime, participants were required to complete a "tasting scale" that rated the food prime on a number of attributes. These included pleasantness, intensity of flavour and richness (Appendix H). The control prime used in for this research was a 9cm X 6cm image of Monets "Lilly Pads". Participants were required to rate the control prime by completing a stimulus rating scale (Appendix I). This accessed a number of the images attributes including pleasantness, intensity of colour and richness of detail. The scale was designed to be closely matched to the chocolate tasting scale

2.8 Computer Tasks

2.8.1 Visual Dot Probe Task (Experiments 2 and 3)

The Visual Dot Probe Task (VDP) is a common paradigm used to indentify biased information processing. The task simultaneously presents words or images to participants (one of these would salient stimulus in this case food and the other neutral). Stimuli are a presented for a short presentation time (usually between 100 ms and 500 ms) after which a probe (usually a cross hatch) appears in the one of the spaces previously occupied by the experimental picture pair. The participant's task is to identify the position where the probe appeared by pressing a response button, this reaction time is used to calculate attentional bias. Attentional bias would be demonstrated by a significantly quicker response to personally relevant stimuli compared to neutral stimuli. (Figure 1.1 shows an outline of a typical VDP trial).

In regards to methodology, VDP tasks designed for appetite research have used both pictorial and word representations of food stimuli, however current consensus indicate that that tasks that use pictorial based stimuli are the more ecologically valid (Brignell, 2009). The VDP tasks used in this thesis were specifically designed for the research studies (and therefore their content varies between research studies. All VDP programs were run on E-Prime [Version 1.0 Psychology Software Tools, Inc; Pennsylvania USA]. Both experiments were conducted in the social psychology laboratory at Swansea university and run using a Dell Optiplex 330 system [Dell House, UK] using a 15" display LED display (32 bit, 1024 x 768 pixels) The stimuli used in the both VDP tasks came from a set of colour photographs which had been in a previously published dot probe task (Tapper, Pothos, Fadardi, & Ziori, 2008). The photos could be categorized into two groups' common household items and food items. All stimuli had been rated as being representative of its category. When chosen stimuli pairs for the dot probe tasks, time was taken to assure that both the neutral and food items had closely matched in regards to visual characteristics. A copy of the stimuli set used in these experiments can be seen in appendix L

Figure 2.1

Diagram of a typical experimental trial on a VDP task

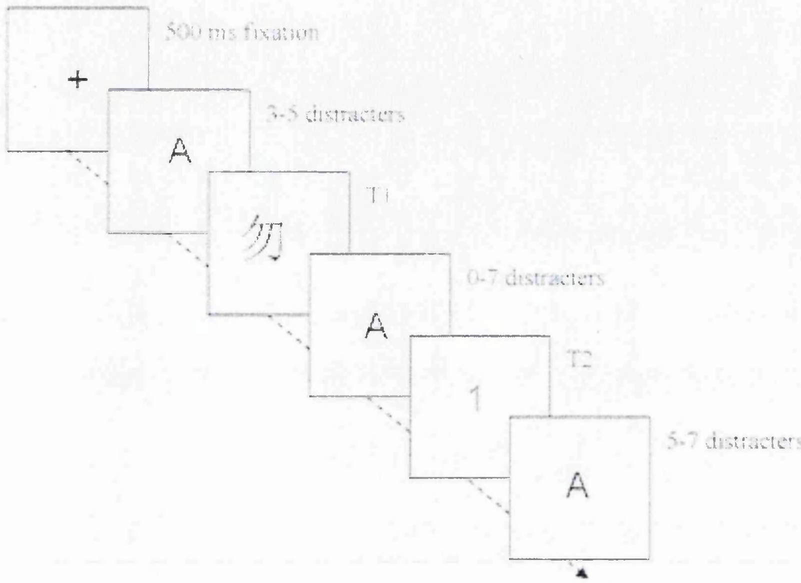
2.8.2 Attentional Blink Task (Experiment 4 and 5)

If distracted individuals find it difficult to maintain their focus on goal relevant information (Lawrence, 1971). Certain types of stimuli are more salient to individuals, and are therefore more likely to capture our attention and lead to distraction. A commonly used paradigm that is employed to study the disruptive effects of" distracters" on behaviour is rapid serial visual processing (RSVP). A typical RSVP paradigm will present the participants with a sequence of visual stimuli in rapid succession (appearing in the same spatial location on the screen); a participant's task is to identify the presence of a predefined target among the stream of images (Dux & Marois, 2009; Piech, Pastorino, & Zald, 2010). It is hypothesized that if the images presented during RSVP are very salient to the individual, they will serve as distracters and subsequently hinders the detection of the target stimulus.

An interesting phenomenon commonly observed during RSVP research is the attentional blink, when stimuli are presented using RSVP accuracy is consistently high for the first target stimuli however the second target is often missed if presented between 200ms-500ms after the first target. This performance decrement is known as "Attentional Blink (AB)", it is suggested that AB reflects competition between the different stimuli for attentional resources (Dux and Marois et al. 2009). When the second target is a motivationally salient ore motional stimulus, the AB is much reduced. For example, Shapiro, Caldwell and Sorensen (1997) found that the AB was abolished when the second target stimulus in an RSVP stream was the participants own name. Other studies, which have used emotional words (or Chinese ideographs, which vary in emotional valence) as target stimuli, have found that the detection rate is improved when the second target stimulus is a negative or aversive stimulus, rather than a neutral stimulus (Anderson, 2005). This research suggests that emotional stimuli, such as negative words, have a special attentional status and are more readily detected than neutral stimuli.

The AB tasks used in this thesis were specifically designed for the experiments in chapter 5. The AB task used in Experiments 4 and 5 consists of 186 trials during which a RSVP stream consisting of the following sequence was displayed 5 distracters, T1 (numeric), 3 distracters, T2 (neutral stimuli) 3 distracters. Each trial started with a 600ms fixation cross followed by the RSVP stream of distractors and targets. Each item in this stream was displayed for 100 ms. Figure 2.2 contains a diagram outlining the presentation of the stimuli during a single trial of the AB task. At the end of each trial participants was required to identify the content at T1 and T2 from multiple choice selections.

Figure 2.2



A representational diagram of a typical experimental trial on the AB task

2.8.3 Conditioning Novel Stimuli

The novel stimuli in Experiments 4,5 and 6 were Chinese ideograms. These were selected as they are neutral images which participants would find distinctive but would also be unfamiliar. All symbols used in this experiment were screened by a fluent mandarin speaker to ensure that they had no direct or indirect association with food. They were also selected as they appeared to be similar in visual complexity. All stimuli were black and white images (white symbol on a black background). They were 163 pixels wide and 145 pixels tall. These Chinese symbols were used in the evaluation, conditioning and AB tasks.

All symbols were rated in a pilot study to insure that they were matched in regards to how perceived attractiveness (N=39). Participants were presented with a rating question which contained nine Chinese characters from which stimuli in the conditioning and attentional blink tasks would later be selected. They were asked to provide a rating of how attractive they found each Chinese character on a scale of

0 ± 5. A high score indicated that they found the symbol to be highly attractive. A between subjects one way ANOVA revealed that there was a significant difference in regards attractiveness ratings (F (4,304) =5.048 p=0.000). Planned comparison revealed that there were no significant differences in rated attractiveness of symbols 1 and 2 [t (38)-1.220 p=0.230], 2 and 3[t (38) =-1.643 p=0.109] and 1 and 3 [t (38) -.488 p=0.628]. Therefore these Chinese ideograms were selected as Conditioned Stimuli (CS+). Non rewarded stimuli were chosen which closely matched the visual characteristics of these stimuli (CS-). The stimuli used in the conditioning task are shown in Figure 2.3.

Figure 2.3

Conditioned Stimuli
(CS+)

Non Rewarded Stimuli
(CS-)

Stimuli set used in the cue conditioning task

2.8.4 Cue Conditioning Procedure

The training task used to condition participant's symbol preference was based upon the work of Brunstom et al. (2005) Three black boxes were presented on screen; participants were instructed that they would be required to find a red rectangle that was hidden inside one of the three boxes. When participants found a red rectangle they were required to eat a red sweet. For each trial participants would select one of the three boxes. At this point their selected box would reveal either a red or blue rectangle; within this rectangle a CS pattern was displayed. This rectangle would remain on screen for 5 seconds. The ordering of each CS-US pairing was randomized, however to establish appropriate CS-US contingencies, the co-occurrence of a red rectangle and a particular CS pattern was predetermined from the outset. In this way each CS pattern was paired with a sweet 90%, 50%, 10% or 0% of the time. To check awareness of rectangle colour participants were asked to report how many times they found a red rectangle at the end of the task. This task was run using visual basic and responses were made using the mouse.

2.8.5 Cue Evaluation Task

In Experiments 4, 5, 6 participants were required to evaluate novel stimuli at two time points i.e. baseline and post conditioning. Both evaluation tasks used in this experiment were based on a previously published task (Brunstrom et al. 2001;. 2005). The computerized task required participants to make paired comparisons of stimuli. During each comparison participants were asked to select the symbol they most preferred. The participants were instructed "you will see two patterns on the screen; I would like you to choose the one that you prefer by selecting it with your mouse. Do not think too hard; just go with your first impressions. The six Chinese ideograms were compared with each other in every combination, with every possible comparison being presented twice (left-right position). This resulted in a total of 30 randomized comparisons. Preference scores were derived from the total number of times each pattern was selected during evaluation; preference scores would therefore range between 0-10. This task was run using visual basic and participants made their responses using a mouse.

2.9 Electroencephalographic (EEG) Recording

The EEG was continuously collected during tasks using the Bio Semi Active Two System (Bio semi, Amsterdam) and edited off-line with BESA (Version Research 5.3, Germany).Voltage recordings were performed on the scalp in accordance with the 32+2 system in Fp1-2, AF3-4, F3-4-Z, F7-8, FC1-2, FC5-6, C3-4-Z, CP1-2, CP5-6, T7-8, P3-4-Z, P7-8, PO3-4, O1-2-Z, plus CMS (Common Mode Sense) and DRL (Driven Right Leg) as reference channels from a 32+2 channel elastic Electro-cap. The bandwidth was set between 0.3 and 40 Hz with a sampling rate of 16384 Hz. All electrode impedances were at or below 50 kΩ. The prestimulus to post stimulus epoch of EEG was recorded from 300 ms prestimulus to 600 Ms post stimulus. The ERP component of interest in Experiments 4, 5, 6 was P300; this was defined as the peak positive amplitude occurring within the 258 to 408 ms time window following the presentation of the CS (Experiments 4 and 5) or stimuli item (Experiment 6).

Chapter 3

How the pull of food relates to reward sensitivity and eating behaviour

Experiment 1

How the pull of food cues relates to reward sensitivity and eating behaviour

3.1 Introduction to Experiment 1

The literature reviewed in Chapter 1 provided strong support for proposals that body weight and BMI are dependent on individual differences in eating behaviour. [These eating styles include an increased sensitivity to reward, hedonic eating, high dietary restraint, impulsivity and external eating]. The Dutch Eating Behaviour Questionnaire (DEBQ) (Van Strien et al. 1986) and the Three Factor Eating Questionnaire (TFEQ) (Stunkard and Messick, 1985) are two commonly used instruments used to indentify different eating styles. A large number of publications have found that the eating patterns measured by sub factors of the TFEQ and DEBQ predict BMI and weight gain (Blundell et al. 2005;Blundell & Finlayson, 2004; Bryant, 2008; Dykes, Brunner, Martikainen, & Wardle, 2004).

Chapter 1 also identified a number of ways in which hyper-responsivity to food cues in the environment (biased processing of food cues, craving and cue reactively) may influence an individual's propensity to gain weight. When these behavioural factors interact within an obesogenic environment they are likely to promote weight gain. These effects appear to be particularly influential in promoting overeating in vulnerable populations (dieters, obese individuals and those which were previously obese). Individuals whose eating behaviours put them at increased risk of overeating have been found to pay enhanced attention to food cues in laboratory environments (e.g. Brignell et al. 2009; Hollitt, et et al. 2010; Tapper et al. 2008, 2010). This heightened responsively to food cues has been shown to predict weight gain over a twelve month period (Calitri et al. 2010). These associations have led to the postulation that overeating is a direct consequence of heightened responsivity to food cues. However equally the extent to which an individual pays enhanced attention to food cues appears to be reliant on eating style.

In 2009 Lowe et al published a paper outlining a new measure of eating behaviour -the Power of Food Scale (PFS) . This scale had been developed to measure individual responsivity to the pull of hedonic foods in the environment. Lowe et al. (2009) proposes that this measure differs from existing scales measuring the propensity to overeat as it assesses the psychological consequences of living in obesogenic environment. The PFS can be viewed as a general measure of responsivity to food in the environment; and can be broken down into subscales which measure responsivity over three levels of proximity (when food is available but not physically present (PFS available), when food is present but not tasted (PFS present) and when food is tasted but not consumed (PFS tasted). Although the PFS was not designed as a specific measure of food cue responsivity, as the term "food cue" encompasses the sight, smell, presence and taste of food it is likely that what Lowe et al. (2009) terms the "power of food" may be a indirect measure of responsivity to food cues in the environment.

As this scale had not being validated in British population this experiment aimed to explore the relationship between the PFS and other standardised measures of eating behaviour (TFEQ, DEBQ). As the PFS is designed to measure the extent to which individuals respond to palatable foods, a central prediction is that that PFS scores would positively correlate with other predictors of overeating particularly disinhibition (TFEQ) and externality (DEBQ). Being highly responsive to the "power of food" could equally be expressed in a more paradoxical manner; if an individual is aware that their intake is heavily influenced by the pull of food they may endeavour to restrict their calorie intake. Restrained eating may therefore reflect a conscious attempt to maintain a healthy body weight despite having an increased sensitivity to the food environment. From this perspective it remains unclear if PFS scores will be related to high or low dietary restraint. More recent publications exploring the PFS have indicated that that the PFS scales moderately correlate with the TFEQ measures of disinhibition, restraint and hunger (Cappelleri et al. 2009). Although PFS scores were found to be significant predictors of BMI in a non clinical sample these effects were not replicated in clinically obese patients (Cappelleri et al. 2009). Ely, Butryn, Stice and Lowe (2010) additionally found that only the PFS factors related to the anticipation of eating were predictive of binge eating in a sample of undergraduate women.

To summarise, the extent to which an individual will overeat in response to environmental cues is unlikely to be dependent on a sole behavioural factor or eating style. For example the DEBQ measure of externality provides an index of how responsive an individual is to food cues (Brignell et al. 2009). From this perspective external eating can be considered to reflect weak top down control over intake.

However if an external eater is also highly restrained, it is unlikely that they will express their sensitivity to food cues through routine overeating. Instead this vulnerability may be demonstrated in their strict control of calorie intake. Similarly high restraint scores and low disinhibition scores are viewed in the literature as characteristic of successful dieting (Savage, Hoffman and Birch, 2009); whereas the opposite combination of high disinhibition and low restraint is viewed as predictive of stress induced overeating (Haynes, Lee & Yeomans, 2003). From this standpoint it is unlikely that weight status will be predicted by one specific eating style, rather a more feasible prediction is that body weight is dependent on the interactions between top down and bottom up motivators of food intake. [This leads to a more viable proposition that body weight is dependent on the interplay between eating characteristics, personality traits and cognitive mechanisms motivating food intake.]

Finally, an important caveat to note is that there exist a number of other factors which appear to affect the extent to which an individual is able to resist the temptation to overeat. Burger and Stice (2011) propose that the propensity to overeat may be underpinned by heighted neural responsivity to reward. Indices of attentional bias are found to be higher in response to rewarding stimuli (Hepworth et al. 2009). Therefore this experiment will also explore the extent to which reward responsivity (as measured by the BAS_RR scale) predicts eating style and body weight. The ability to successfully regulate behaviour is also likely to influence overeating; therefore the BIS scale will also be included in this experiment. This measures individual differences in the ability to suppress behaviour which has negative consequences. Previous research by Davies, Strachan and Berkson (2004) has shown that obese adults have higher BIS scores. This experiment therefore predicts that high BIS and BAS_RR scores will be related to traditional measures of overeating (TFEQ, DEBQ), BMI and the PFS.

Experiment 1 aims to establish how the factors outlined above contribute to the development of obesity. An online questionnaire survey was distributed to a random sample of the research population (*N*=401) to collect information about a number of eating styles and their relationship to self reported body weight. This questionnaire additionally collected data about sensitivity to reward, hedonic eating and impulsivity. This initial experiment had a number of aims. Firstly many of the experiments in this thesis required participants to be grouped in regards to their scores on common psychometric measures of eating behaviour (e.g. high or low disinhibited eating) the mean data collected in this study will aid in categorization of participant groups. However the main purpose of this experiment was to establish which variables appeared to be influential in predicting weight status. In particular this study included a newly published measure of the pull of food (Lowe et al. 2009). It was predicted based on the previous literature that individual variation in reward sensitivity, responsivity food and eating style would be reflected in body weight. Therefore it is hypothesised that obese and overweight participants will have highest scores on these measures.

3.2 Method

An online survey (Survey Monkey, Portland, Oregon, USA) was used to collect information about a number of different eating styles, responsiveness to reward and self reported body weight. Participants were staff and students studying at Swansea University. As an incentive to complete the questionnaire all participants were entered into a prize draw where one individual was randomly selected to receive a £25 gift voucher.

3.3 Measures

For a detailed account of any of the measures used in this study please refer to the general methodology section. The online questionnaire consistent of several measures including the three subscales of the TFEQ (Stunkard & Messick, 1985), all DEBQ subscales (Van Strien et al. 1986) and the three subscales of the PFS (Lowe et 2009) . Finally the BAS_RR scale measure of reward responsivity and BIS scales was used to measure behaviour suppression. Participants were also required to provide self report of their height (m), weight (kg) and heaviest weight (kg). Participants also provided information about their current diet status, frequency of chocolate consumption, along with demographic information (age, gender).

3.4 Preliminary inspection of data

Kolmogorov-Smirnov and Shapiro Wilks showed that all measures collected in this study were non normally distributed. Therefore where appropriate non parametric analyses were conducted.

3.5 Dependent measures

The main dependent measures of interest in this study were calculated scores for the DEBQ (external eating, emotional eating and restrained eating), TFEQ (disinhibition, cognitive restraint and hunger), reward responsivity (BAS_RR), behavioural inhibition (BIS), PFS [available but not present (PFS available), present but not tasted (PFS Present) and tasted but not consumed (PFS tasted], BMI and heaviest ever BMI.

3.6 Analysis

Cronbach's alpha scores were calculated for each psychometric measure included in this experiment. Spearman's correlations were then conducted to establish any relationships between the measures collected in this study. A Stepwise multiple regression was conducted to establish which measures were the best predictors of current BMI. The data set was categorised into two groups based on weight status (Normal weight vs. obese), Mann Whitney U tests were used to establish whether any of the appetite scores differed in terms of participant's weight category. A logistical regression was conducted to establish which of the above factors predicted weight status. Mulicolineraity between predictors was assessed for both of regression models. Mann Whitney U tests were also used to compare sex differences, and to contrast scores between current dieters and non dieters. The data was also categorised into two groups based on previous weight loss (weight constants vs. weight suppressors). Mann Whitney U tests were then used to compare scores between these two groups.

3.7 Results

3.7.1 Participants

A total of 403 respondents completed the online questionnaire. Mean (±SD) BMI was 23.21 ± 4.22 kg/m^2; mean (±SD) age was 22.86 ± 6.52 years. A large proportion of the respondents were female (*N*=315, 78%). 262 of the subjects who completed the web-based survey had a BMI within what is considered to be a normal weight range (18.5 to 24.9k g/m$^{2)}$(65.5% therefore being categorised of "normal" weight); 6.5% were underweight (BMI <18kg/m2), 18.1% were overweight(BMI 25-29.9 kg/m2) and 6.5 % were classified as obese (BMI>30.0 kg/m2). Of the individuals completing the survey 3.5% did not supply information about their body weight. Finally, in regards to dieting 25.1% of participants stated that they were currently limiting their calorie intake in an attempt to lose weight. Participants were asked to report their heaviest ever weight status, the mean heaviest ever BMI was

25.13±5.13 kg/m^2. Data from respondents who's reported mean BMI was under 18 was removed from the analysis as this BMI may have been reflective of a clinically disordered eating (*N*=14). Additionally respondents who did not supply information about their body weight were removed from the data set (*N*=14). This left a total of 363 participants, mean (±SD) age was 23.06±6.78 and mean BMI was 23.65±4.016. Figure 3.1 displays this samples mean scores (±SD) along with Cronbach's alpha for each of the measures used in this study. Chronbach's alpha scores indicate that one of the scales used in this sample had questionable internal validity; this was BIS (α=0.270).

Table 3.1

Measure	Mean±SD	α
BMI	23.65±4.02	-
Heaviest BMI	25.54±4.94	-
Age	23.06±6.78	-
TFEQ_D	5.69±2.95	0.667
TFEQ_R	8.48±4.97	0.771
TFEQ_H	4.77±3.10	0.723
DEBQ_Ex	3.01±0.55	0.792
DEBQ_R	2.61±1.022	0.934
DEBQ_Em	2.45±0.91	0.910
BAS_RR	7.98±2.07	0.666
BIS	11.86±3.19	0.270
PFS Available	15.44±6.25	0.883
PFS Present	16.97±6.007	0.824
PFS tasted	17.19±5.67	0.854

Mean (±SD) and Cronbach's Alpha for the population sample

Footnote: N=363 (underweight and non reported weight excluded)

3.7.2 Relationships between psychometric measures

Spearman's correlations were conducted to establish the relationships which existed between the measures collected in this study; r and p values for each correlation can be found in the correlation matrix (Table 3.2). The patterns of correlations found between the measures are consistent with previous research. In respect to the Dutch Eating Behaviour Scale, the subscale of external eating was found to have positive correlations with emotional eating, disinhibition (TFEQ_D) and hunger (TFEQ_D). No significant relationship was found between external eating and either measure of dietary restraint. The emotional eating scale was a weak predictor of dietary restraint [TFEQ_R, r =0.2451, DEBQ_R, r=0.287]. Emotional eating was also a moderate predictor of disinhibition (TFEQ_D) and hunger (TFEQ_H). In line with expectations the DEBQ measure of dietary restraint was found to strongly correlate with the TFEQ_R subscale (r=0.828); whereas DEBQ_R was a weak predictor of disinhibition (TFEQ_D). There was no relationship found between DEBQ_R scores and the TFEQ's measure of hunger.

In regards to the TFEQ scale; along with the positive relationships outlined above the TFEQ_D subscale was found to have weak negative correlations with the BIS measure [BIS r=-0.304]. A similar relationship was found between this measure and the TFEQ_R [r=-0.213] and TFEQ_H [r=-0.144]. No relationship was found between any of the TFEQ subscales and the BAS_RR, however this may be influenced by the low internal validity alpha's found for this measure. In respects to the PFS; all three subscales were found to positively correlate with the TFEQ_D, TFEQ_H and the DEBQ measures of emotional and external eating. However in regards to dietary restraint only the PFS subscale measuring the pull "available but not present" was found to predict TFEQ_R and DEBQ_R scores. All PFS subscales were found to have weak negative relationships with the BIS. Only the scales measuring the pull of present and tasted food cues were found to be negatively correlated with the BIS measure of reward sensitivity.

No relationship was found between any PFS subscale and BMI, heaviest BMI or responsiveness to reward (BAS_RR). Current body weight (as measured by BMI) was found to have a weak but positive relationship with the DEBQ measures of emotional and restrained eating (r values <0.2). Again BMI was a weak predictor of TFEQ_R and TFEQ_D score. These relationships were replicated for heaviest ever BMI. A strong positive correlation was found between current reported BMI and heaviest ever BMI [r=0.874]. No other significant relationships were found between the measures and body weight status.

Table 3.2:

	BMI	Heaviest BMI	DEBQ_Ex	DEBQ_Em	DEBQ_R	Available	Present	Tasted	BIS	BAS_RR	TFEQ_D	TFEQ_H	TFEQ_R
BMI		.856**	-.015	.172**	.213**	.081	.018	.027	-.015	.016	.239**	.071	.128*
Heaviest BMI			-.055	.145**	.308**	.061	-.037	-.018	-.049	.027	.261**	.013	.253**
DEBQ_Ex				.460**	.102	.559**	.528**	.648**	-.165**	-.090	.475**	.575**	.050
DEBQ_Em					.305**	.519**	.337**	.415**	-.288**	.027	.737**	.392**	.249**
DEBQ_R						.331**	.083	.084	-.219**	-.054	.368**	.026	.817**
PFS available							.699**	.680**	-.294**	-.024	.576**	.584**	.257**
PFS present								.731**	-.200**	-.132*	.343**	.497**	.045
PFS tasted									-.224**	-.111*	.431**	.531**	.060
BIS										.203**	-.300**	-.158**	-.219**
BAS_RR											-.008	.004	-.059
TFEQ_D												.451**	.342**
TFEQ_H													-.029
TFEQ_R													

Correlation matrix displaying Spearman's R value and P Value [* P>0.05, ** P<0.05]

3.7.3 Predictors of current weight status

Table 3.3

	Beta	S.E	B	VIF	Adjusted R^2
Step 1					
TFEQ_D	0.339	0.071	0.238**	1.00	0.054

Co-efficient for multiple regressions prediction of current BMI

As this study's analysis was an exploratory stepwise multiple regression were conducted to establish which of the above factors were the best predictors of current BMI. Therefore BMI score was entered as the dependent variable. Variables which did not correlate with BMI in previous analyses were not used as predictor variables in this analysis. Also, as heaviest ever BMI was found to strongly correlate with BMI it was not used as a predictor variable. The predictor variables were TFEQ_R, TFEQ_D,DEBQ_R and DEBQ_Ex. Mulicolineraity was assessed between predictors, although there were significant relationships between variables none of the correlation co-efficient exceeded 0.9 therefore it was concluded that there were no strong relationships between variables. The VIF (Variance Inflation Factor) scores (see Table 3.3) are all close to one which confirm that colinearity is not a problem for this model. Using the stepwise method a significant model emerged [F (4,381) =6.272 p=0.000]. This revealed only one significant predictor of current BMI status, namely TFEQ_D. For relevant beta co-efficient and p value refer to Table 3.3. The r square values for this model reveals that 5.6% of the variance in BMI could be accounted for by disinhibition. Every increase in heaviest ever reported BMI was associated with a 0.339 kg/m^2 increase in BMI. Adjusted r^2 revealed that this model generalises well to the general population with only 2% reduction being shown in predictive value.

3.7.4 Differences in appetite scores based on BMI category

Participants provided self report of their height and weight which were used to calculate their current BMI. Based on these calculations participants were categorised into three groups based on BMI category (normal weight 18.5-24.9, overweight 25-30 and obese >30.1). As there were only 26 participants who were classified as obese the data from the obese and overweight category was combined for analysis [*N*=99]. Mean±SD BMI for the normal weight group was 21.72±1.69 and 28.79±3 for the overweight group. As expected the two groups differed significantly in regards to current BMI [*U* (363) =3.00 *Z*=-14.675 *p* =0.00] and heaviest ever reported BMI [*U*(363)1250.5 Z=-11.35 *p*=0.00]

Table 3.4:

	Measure	Normal Weight (*N*=264)	Overweight and Obese (*N*=99)
*	BMI	21.72±1.69	28.79±3.89
*	Heaviest BMI	23.39±2.69	31.23±5.04
*	Currently Dieting	N=55	N=42
*	TFEQ_D	5.29±2.79	6.75±3.11
*	TFEQ_R	8.13±5.02	9.51±4.73
	TFEQ_H	4.71±3.18	4.93±2.91
	DEBQ_Ex	3.03±0.53	2.99±0.62
*	DEBQ_R	2.52±1.05	2.86±0.92
*	DEBQ_Em	2.37±0.87	2.66±0.98
	BAS_RR	7.98±2.07	7.98±0.29
	BIS	11.96±3.21	11.59±3.16
*	PFS Available	15.05±6.14	16.49±6.44
	PFS Present	16.96±5.61	17.81±5.83
	PFS Tasted	16.79±6.04	17.46±5.92

Mean (± SD) demographics of normal weight and obese group

*Footnote: * indicates significant differences between normal weight and overweight/obese participants.*

Pearsons Chi Square revealed that a greater proportion of obese participants were currently dieting [x^2=17.141 *p* =0.00]. Mann Whitney U tests were conducted to establish whether any of the appetite scores differed in terms of participant's weight category. The independent variable in this series of analyses was weight category (normal weight, overweight) where as the dependent variable was the appetite measure of interest. Mean ±SD scores for each group based on weight category are shown in Table 3.4. Overweight participants scored significant higher on a number of measures; these were the DEBQ's measure of emotional eating scores [*U* (363) =10693 *Z*=--2.669 *p* =0.008] both measures of dietary restraint

[DEBQ, U (363) = 9783.5 Z=-3.216 p =0.001, TFEQ U (361) =-11108 Z=-2.205 p =0.027] and TFEQ_D [U (363) =9414 Z=-4.124 p =0.00]. Body weight did not influence external eating scores [U (363) =12612.00 Z=-0.404 p =0.686] with the mean data indicated that both groups displayed moderate levels of external responsiveness to food cues.

Although the obese/overweight group had higher mean scores on all three power of food subscales scale; the only significant differences between weight categories were found in regards to the pull of available but not present food cues [U(636) = 11263.5 Z=-2.030 p =0.042]. This indicates that individuals who overweight were only more responsive to the pull of food cues in situations where food was availability but not present. No significant differences based on BMI group were found in scores on TFEQ_H [U (363) =-12256.5 Z=-0.916 p =0.360], BIS [U (363) =12323 Z=-.840 p =0.401] or BAS_RR [U (363) =-13003.5 Z=-0.073 p =0.942].

3.7.5 Predictors of weight category

A logistical regression analysis was conducted to predict weight category (normal weight vs. overweight). The dichotomous variable of BMI (normal weight compared to overweight) was used as the model's dependent variable. All other variables outlined in the previous model were used as predictor variables. Mulicolineraity was assessed between predictors, although there were significant relations between variables none of the correlation co-efficient exceeded 0.9 therefore it was concluded that there were no strong relationships between variables. The VIF scores (see Table 3.3) are all close to one which confirm that colinearity is not a problem for this model.

A forward stepwise regression found a significant model for predicting weight category [x^2 (1, 3) = 233.875 p =0.00]. The model showed that there were three significant predictors of weight category. These were heaviest ever reported BMI, dietary restraint (TFEQ) and scores on PFS taste subscale. Nagelkerke R^2 square of 0.700 indicates a moderately strong relationship between predictors and weight category grouping. The prediction success of this model was generally high (93.8 % for normal weight, 73.2% for overweight participants). The beta value for the predictor of dietary restraint is negative, indicating that this eating pattern was associated with lower BMI. Heaviest ever reported BMI accounted for the majority of the variance in this model for every increase in heaviest ever BMI the respondents were 2.1 times more likely to be classified as overweight. TFEQ_R and PFS taste had less of a contribution to the model; for each increase in PFS availability score participants were 0.91 times more likely to be classified as overweight. Whereas each increase in TFEQ_R was associated with participants being 1.07 times less likely to be classified as overweight.

Table 3.5:

	Beta	S.E	Wald Statistic	Exp (B)
Heaviest BMI	0.747	0.088	71.95 P=0.00	2.11
TFEQ_R	-0.087	0.041	4.513 P=0.034	0.917
PFS Taste	0.069	0.033	4.36 P=0.037	1.071

Co-efficients for logistical regression prediction of weight category
Note: r^2: Cox and Snell= 0.483, Nagelkerke Model= 0.700;
Homer and Lemeshow $x^2(8)$ =33.823 p =0.00

3.7.6 Sex differences

To establish if there were sex differences within the data set male responses (*N*=83) were compared with female responses (*N*=280). From a behavioural standpoint a higher proportion of females reported that they were "currently dieting" (*N*=82) with only nine males reported that they were currently restricting their calorie intake in an attempt to lose weight. Pearsons Chi Square [x^2=13.855 p <0.00] confirmed that dieting was more frequently reported amongst female respondents. There were no sex differences in BMI status [Current BMI U (363)=1152.00 Z=-0.117 p =0.907, Heaviest BMI (U (363)=11105.5 Z=-0.401 p =0.688]. Females had significantly higher restraint scores [TFEQ_R (U (363)=7631.500 Z=-4.759 p =0.000, DEBQ_R (U (363)=6919.50 Z=-5.282 p =0.00].Females also had significantly higher scores on the measures of emotional eating [U (363)=8403.00 Z=-3.833 p =0.00] and disinhibition [U(363)=8626 Z=-3.584 p =0.000]. The only sex differences found in PFS scores were for the subscale measuring the pull of available but not present food cues [U (363) =9845.500 Z=-2.117 p =0.034]. The males in this sample were found to have significantly higher BIS [U (361) =6912 Z-5.631 p =0.000] and BAS Reward Responsiveness scores [U (363) =-8973.00 Z=-3.191 p =0.001]. Indicating that males were more responsive to reward and less able to successfully suppress behaviour.

3.7.7 Dieting Status

To establish the effect of current diet status on eating characteristics, participants who reported that they were currently dieting (N=97) were compared to non dieters (N=266). Participants who were currently dieting had significantly higher current BMI [U (363) =8516.00 Z=-4.957 p =0.00] along with heaviest ever body weight [U (363)=7575 Z=-5.949 p =0.00]. In line with predictions, current dieters had significantly higher score on both TFEQ and DEBQ measures of dietary restraint [DEBQ_R U (363) =3543.00 Z=-10.255 p =0.00]; TFEQ_R [U (363) =3515.00 Z=-10.628 p =0.00]. Current dieters also reported higher scores on the TFEQ_D [U (363) = 6539 Z=- 7.17 p =0.00] emotional eating (U (361) =8224.5 Z=-5.288 p =0.00) and PFS [U (363) =10119.5 Z=-3.14 p =0.002].

Participants were asked to report their heaviest ever weight; this measure was used to calculate whether participants had successful maintained weight loss. Three participants had not reported a heaviest ever weights so were excluded from the analysis [N=360]. Percent of previous weight loss was calculated by dividing current BMI by heaviest ever reported BMI, and subtracting this value from zero. The value obtained presents the percentage decrease in BMI from heaviest ever reported weight. Participants were allocated into two groups using a median split (those who were weight suppressors (N=180) and those who were weight constant (N=180). On average weight suppressors reported an 11.74 % ± 7.02 decrease in BMI, whereas reported mean change in BMI was -1.62 %±3.22 in the weight constant group. Mann Whitney U tests confirmed that these two group different significantly in regards to change in BMI (U (360) =-8936.5 Z=-4.40 p =0.00). Individuals who were classified as "weight suppressor" had higher current BMI [U (360) =12695.5 Z=-3.626 p =0.00] and highest ever reported BMI [U (360) =23010.5 Z=-9.35 p <0.00].

The weight suppression group were found to have significantly higher dietary restraint [DEBQ_R U (360) =11891.00 Z=-3.922 p =0.00, TFEQ_R [U (360) =3.669 p =0.000]. This group were also found to have lower external eating scores [DEBQ U (360) =-14485.500 Z=-1.655 p =0.098 one tailed p =0.049] and trait hunger (TFEQ_H) [U (360) -2.990 Z= -1.988 p = 0.047]. Weight suppressors and weight constants were not found to differ significantly on any other measure [p >0.05].

Table 3.6:

	Measure	Weight Suppressors (*N*=180)	Weight Constants (*N*=181)
*	BMI	24.51±4.63	22.81±3.11
*	Heaviest BMI	27.885.32	23.21±3.12
	Currently Dieting	N=64	N=33
	TFEQ_D	5.99±2.89	5.41±2.98
*	TFEQ_R	9.74±5.07	7.209±4.57
*	TFEQ_H	4.41±2.90	5.13±3.25
*	DEBQ_Ex	2.97±0.55	3.06±0.56
*	DEBQ_R	2.84±1.04	2.39±0.95
	DEBQ_Em	2.45±0.93	2.45±0.88
	BAS_RR	8.04±2.19	1.93±0.14
	BIS	11.8±3.24	11.9±3.15
	PFS Available	15.32±6.47	15.59±6.05
	PFS Present	16.66±5.75	17.33±6.24
	PFS Tasted	16.8±5.76	17.34±5.55

Mean (± SD) demographics of weight suppressors and weight constants.

*Footnote: * indicates significant differences between normal weight and overweight/obese participants $P<0.05$.*

3.8 Discussion

This study explored the relationships that exist between a number of measures of eating behaviour and body weight status. A number of measures were found to positively correlate with BMI; these were disinhibition (TFEQ_D), both dietary restraint scales and emotional eating. However all correlation co-efficients indicated a weak relationship with BMI. The weak correlations found in this sample may be a result of the limited range in BMI values. The positive relationship found between TFEQ_D and BMI replicates findings from the research literature (Blundell, et al. 2005, Dykes, Brunner, Martikainen & Wardle, 2004; Lawson et al. 1995). These papers outline a strong relationship between disinhibited eating and body weight, however as mentioned for this sample TFEQ_D was a weak predictor of BMI (r =0.27). Previous research has indicated that obesity is associated with high disinhibition (Boschi et al. 2001, Provencher, Drapeau, Tremblay, Despre and Lemieux 2003). When this survey's respondents were classified by weight category obese participants had significantly higher TFEQ_D scores. The relationship found between disinhibition and body weight supports this thesis's predictions that diminished top down control (poor self regulation) contributes to overeating (Chapter 1).

A positive correlation was also found in this sample between dietary restraint and BMI. Previous examination of the association between restraint and body weight have produced conflicting results; the literature outlines both positive (Janelle & Barr, 1995) negative (Foster, Wadden, Swain, Stunkard, Platte & Vogt 1998; Williamson et al. 1995) and no correlations between restraint measures and BMI (Lawson et al. 1995, Provencher et al. 2003). Although the data from this sample indicates that high dietary restraint is associated with increased body weight; the extent to which measures of dietary restraint are reflective of unsuccessful dieting remains unclear.

In this sample individuals classified as weight suppressors reported a considerable weight loss (10% or more of body weight). This group had significantly higher dietary restraint scores compared to individuals who were weight constant. This implies that high dietary restraint (as measured by both the TFEQ and DEBQ) reflects successful dieting strategies. However somewhat contradicting this prediction, the weight suppression group had highest current BMI (mean 24.51±4.63 compared to 22.81±3.11). Mean BMI indicates that weight suppressors although heavier than weight constants were at the upper end of normal body weight. However as the participant demographic in this experiment was predominately females in their early twenties it may be proposed that the higher dietary restraint scores seen in this group may begin to reflect unsuccessful dieting in later years. This is supported by the finding that obese participants in this sample also had significantly higher dietary restraint scores. An alternative explanation for this finding is that as measures of weight loss were self reported (based only estimation of heaviest ever weight/ current body weight), it is quite possible that participants were not accurate at reporting how much their weight had fluctuated. As individuals with high dietary restraint would be focused on weight loss goals and it could be proposed that this may lead to overestimation of actual weight loss.

An additional predictor of BMI in this sample was emotional eating; this relationship is well established within the appetite literature. Obesity has been linked to higher incidences of emotional eating in non clinical populations (Lluch, Herbeth, Mejean and Siest 2000). In line with Lluch et al. (2000) findings, female participants in this survey also scored significantly higher on the DEBQ emotional eating scales. Although the relationship between body weight and emotional eating in this sample was weak; emotional eating was found to be a significant correlate of all other predictors of BMI. This suggests that emotional eating may be a mediating rather than a direct predictor of bodyweight.

This study replicated the well explored relationships found between the TFEQ and DEBQ subscales. In this sample obese participants were found to have significantly higher emotional eating scores, dietary restraint and disinhibited eating. However not all of the DEBQ and TFEQ's measures appeared to be characteristic of the propensity to gain weight. Obese participants were not found to be more externality responsive than those of normal bodyweight. This supports studies which have questioned the extent to which sensitivity to food cues is able to accurately predict weight gain (Lluch et al. 2000). This study was interested in exploring the relationship between the newly developed PFS and subscales of the TFEQ/ DEBQ. All three subscales of the PFS were found to positively correlate with the TFEQ_D, TFEQ_H and the DEBQ measures of emotional and external eating. Although these relationships were moderate at best with none of the correlation co-efficients reached above 0.75 this provides supports for claims that the TFEQ, DBEQ and PFS are tapping into similar but distinct aspects of overeating (Cappelleri et al. 2010, Ely et al. 2010).

In regards to dietary restraints relationship with the PFS; only the PFS subscale measuring the pull "available but not present cues" was found to predict TFEQ_R and DEBQ_R scores. Previous research has found only a weak correlation between the TFEQ measure of dietary restraint and PFS (Cappelleri et al. 2010). This finding appears to indicate that restrained eating is high in individuals who are experiencing strong anticipatory desire to consume food; this may reflect an attempt to counteract temptation. This was also the only PFS measure that was found to be significantly higher in obese respondents.

All three subscales of the PFS were found to weakly correlate with the BIS; this leads to the interpretation that individuals who have decreased ability to suppress behaviour associated with negative consequences are more sensitivity to the pull of environment food cues. Also only the PFS subscales measuring the pull of present and tasted food cues were found to be related to the BIS measure of reward sensitivity. This relationship was negative, lending support to the argument that obesity develops in response to a lowered signal capacity within reward circuitry (Stice et al. 2010). Such dysfunction would predict that an individual would need to consume higher amounts of rewarding food to experience the equivalent degree of reward as an individual with normative reward circuits (Wang et al. 2002). However the extent to which other data from this study substantiates this prediction is limited, as obese participants were not found to have significantly higher BAS_RR scores.

The PFS was not found to be predictive of BMI or heaviest ever BMI; the relationships outlined in this experiment instead appear to indicate that the PFS have a indirect influence on weight gain. For example strong relationships were found between the PFS and TFEQ_D and DEBQ measure of external eating, both of which were found to be predictive of BMI. This suggests that being highly responsive to food or food cues may only lead to weight gain, if an individual has poor self regulation of their eating behaviour. It may be argued that disinhibition reflects poor top down control. In line with this prediction the regression model conducted to examine which factors best predicted current BMI found TFEQ_D to be the only significant predictor of current BMI. However it is important to note that this factor made only a small contribution to predicting body weight.

A number of studies have shown disinhibition to be strongly associated with longitudinal weight gain (Hays and Robert 2008). Hays & Roberts (2008) modelled weight gain over a twenty year period and found that the extent to which disinhibition predicted obesity was moderated by dietary restraint. This relationship was replicated in a study by Williamson et al (1995) which examined the associations between TFEQ_D and restraint in a large female sample. However when a logistical regression was used to predict weight status (classify whether participants were obese or of normal body weight). Three significant predictors of weight category were established there were dietary restraint (as measured by the TFEQ_R), responsivity to the taste of hedonic food cues (PFS) and heaviest ever BMI. This model portrays that high hedonic eating along with a pre-existing vulnerability to weight gain predicted obesity. Whilst high dietary restraint and low external eating appear to be protective factors against weight gain

3.9 Summary of main findings

- Disinhibition, dietary restraint scales and emotional eating positively correlate with BMI. This supports the prediction that diminished top down control may contribute to overeating.

- Correspondingly, respondents who were classified as overweight or obese had significantly higher scores on measures of emotional eating, dietary restraint and disinhibition. This group also had greater responsivity to anticipatory reward.
- A regression model revealed that current high body weight was determined by high disinhibition. However a history of being overweight accounted for the majority of the variance in current BMI status.
- A Logistical regression model revealed that the best predictors of current weight status (whether respondents were obese or of normal body weight) were dietary restraint (as measured by the TFEQ_R), responsivity to the taste of hedonic foods (PFS), and heaviest ever BMI. This model portrays that when an individual who has a pre existing vulnerability to weight gain is also responsive to the taste of hedonic food they have an increased the probability of being overweight. Whilst high dietary restraint appeared to protect against weight gain.
- This study replicated the well explored relationships found between the TFEQ and DEBQ subscales. But also explored the how the newly developed power of food scale relates to these measures. All three subscales of the PFS were found to positively correlate with the TFEQ_D, TFEQ_H and the DEBQ measures of emotional and external eating.
- As these relationships were moderate this strengthens claims by Lowe et al. (2009) that the PFS measures a separate component of overeating to existing scales. Only the PFS factor associated with anticipation of obtaining food reward (PFS availability) was related to restrained eating. The PFS subscales weakly correlated with BIS, which may indicate that difficulty in suppressing behaviour associated with negative consequences is related to sensitivity to food reward.

- PFS was initially used as a measure in Experiment 1 in the hope that it might serve as a indirect measure of food cue responsivity. The subscales contained in the PFS measure how reactive individuals are to food cues that are in sight, taste or merely indicating availability. It was predicted that these measures would have strong relationships with those related to opportunistic eating (TFEQ_D, DBEQ_Ex).

- Experiment 1 found the PFS scale to be unrelated to body weight. The relationships between the PFS subscales and measure of opportunistic eating were also weak. Due to these non significant/weak relationships it was decided to not use the PFS as a variable in any future experiments.
- Future experiments in this thesis will explore food cue responsivity from a more behavioural level and will use measures of attentional capture/ attentional bias to food cues.

Chapter 4

Measuring attentional bias to food cues using the visual dot probe task

4.1 Measuring attentional bias to food cues

If food cues are indeed more salient for individuals who are susceptible to weight gain it can be proposed that this hyper-sensitivity to food information may be measured at both a neural and behavioural level. Addiction research has shown that drug cues "grab attention" and elicit automatic responses in habitual drug users. Attentional biases for drug cues have been indentified in smokers, drug users and alcoholics (Bauer & Cox, 1998; Cox, Hogan, Kristian, & Race, 2002; Gross, Jarvik, & Rosenblatt, 1993; Lubman, Allen, Peters, & Deakin, 2007, 2008; Lubman et al., 2009; Stormark, Laberg, Nordby, & Hugdahl, 2000; Warthen & Tiffany, 2009; Waters et al. 2007; Waters & Feyerabend, 2000). [It is predicted that attentional bias plays a functional role in maintaining addictions; correspondingly a number of publications have demonstrated that drug users who have elevated attentional bias have poorer treatment outcomes (Cox, et al., 2002; Marissen et al., 2006; Waters et al., 2003, 2004)].

A key focus of this thesis is to explore whether the models shown in the addiction literature also apply to food cues and overeating. Indices of attentional bias are calculated by measuring participant's performance on attention tasks. A number of paradigms are used to investigate food processing bias (FPB). Attentional bias to food stimuli has been measured using the visual dot probe task (VDP), stimulus response compatibility task (SRC), modified stroop task and the attentional blink (AB) task. There are also attempts to measure memory and judgments biases within appetite research but these paradigms are typically used in the eating disordered populations (Williamson, Muller, Reas, & Thaw, 1999). See Table 4.1 for a overview of the current research literature.

A commonality between these tasks is that they compare response times to food stimuli with neutral stimuli. Attentional tasks have used pictorial and word stimuli; however current consensus is that pictorial stimuli provide a more ecologically valid measure (Brignell et al. 2009).

4.1.1 The Stoop Task

The stroop task (Stroop, 1935) records the time it takes for participants to report the colour ink that a colour word is printed in. The time taken to report the ink colour is consistently quicker for congruent trials (colour word and ink colour are the same) compared to incongruent trials (colour word is different to the ink colour). It is proposed that differences in reactions times between the two trials types are reflective of difficulty in disengaging from the meaning of the stimulus. These effects provide an example of how competition for cognitive resources reduces response latencies and accuracy (Dobson & Dozois, 2004). [A frequent criticism of the stroop task is that it is difficult to establish whether increases in response latencies are reflective of attention capture or if participants are trying to draw their attention away from the stimulus]. The emotional stroop task employing food related words has been used in appetite research. Longer reaction times for food related words relative to neutral words would indicate a processing bias for food information. Brooks et al. (2011) propose that when pictorial stimuli are used on the stroop task larger effect sizes are produced as food images provide more contextual information than food words alone.

The majority of studies using the modified stroop have used participants with eating disorders (for review see Brooks et al. 2011; Dobson & Dozois, 2004). Differences in stroop performance have also been compared in groups considered to be at risk of overeating. These include external eaters, individuals with high dietary restraint and high disinhibition. The stroop task has also been used to predict changes in BMI across a twelve month period (Calitri et al. 2010). Tapper, Pothos, Fadari and Zoiri (2008) examined the role of dietary restraint and disinhibition on participant's response to food words on the emotional stroop task. This was a cross sectional study (N= 224) which was conducted in Greece, Iran and the UK. Participants were significantly slower at naming the colour of food words. Individuals who had high dietary restraint but who were not currently dieting displayed greatest attentional bias. Whereas restrained eaters who were currently dieting had significantly lower attentional bias.

Assessment of stroop performance of individuals categorised as high external eaters present mixed findings. Johansson, Ghaderi and Anderson, (2004) found no differences between high and low external eater's responses to food or body words on the stroop task. However Newman, O'Connor and Conner, 2008) comparison of high and low external eaters on a computerised stroop task found significant differences in response latencies.. When stress levels were manipulated high external eaters displayed greatest bias towards snack words. No bias was found for meal words or meal foods (Newman. O'Connor and Conner. 2008). Rofey et al. (2003) found further evidence for the influence of mood on the stroop task. In a bulimic sample FPB was only demonstrated when participants were experiencing negative mood. This led Rofey et al. (2003) to propose that negative mood increases attention to "threatening" stimuli in their environment.

Caltri et al. (2010) explored the extent to which stroop performance could predict weight change over the course of 12 months. Findings revealed that attentional bias to unhealthy food words were predictive of weight gain. Whereas attentional bias to healthy foods predicted weight loss. The stroop task appears to be a useful index of food processing bias giving support for the hypothesis that obesity risk factors (i.e. external eaters, binge eaters, dietary restraint) are associated with enhanced processing of food words.

4.1.2 Visual Dot Probe

The visual dot probe task (VDP) (Macloed, Mathews and Tata, 1986) is a paradigm used measure attentional bias. The task was initially used to measure the processing of emotional stimuli in anxious or phobic participants. The task is thought to measure both hyper vigilance and avoidance of stimuli. The task simultaneously presents words or images to participants (one of these would be a salient stimulus and the other neutral). Stimuli are a presented for a short presentation time (after which a probe (e.g. cross hatch) appears in the one of the spaces previously occupied by the picture pair. The participant's task is to identify the position where the probe appeared by pressing a response button. Attentional bias would be demonstrated by a significantly quicker response to personally relevant stimuli compared to neutral stimuli. In appetite research VDP studies have used both pictorial and word representations of food stimuli. However more recently images have been the most often used by researchers which may be seen as more ecologically valid that word stimuli (Brignell et al. 2009). Additionally, it is worth noting that there are a number of methodological differences (e.g. stimuli duration) in published VDP tasks.

To summarise the findings of the VDP in appetite; Mogg, Bradley, Hyare and Lee (1998) found that FPB was increased when participants are hungry. However attempts to use the VDP task to show that obesity risk is reflected in elevated FPB have revealed inconsistent findings. For example although Caltri et al. (2010) demonstrated that stroop performance was an accurate predictor of BMI change, participants performance on the VDP did not predict weight gain. Johansson, Ghaderi, & Andersson (2004) found that high external eaters' avoided food related stimuli on VDP. This at first glance, contradicts the proposed hypothesis that external eaters would be more responsive to food cues in their environment. However Johansson et al. (2004) purported that these findings are representative of a coping mechanism used by external eaters in an attempt to maintain a healthy body weight. This works on the assumption that an individual who is high in trait externality is aware of their vulnerability to gain weight and also their tendency to be hyper-responsive to food stimuli in their environment. This awareness causes them to intentionally direct their attention away from food relevant stimuli. Equally, the "ironic process theory" by Wegner (1994) would propose that an individual who is actively avoiding "food thoughts" may need to attend to relevant food stimuli on a dot probe task in order to avoid them. This may also account for the longer reaction times to food cues seen in Johansson et al. (2004) work.

This avoidance of food stimuli by external eaters has not been replicated in other VDP studies. Brignell, Griffiths, Bradley and Mogg (2009) found that external eating was associated with hyper-vigilance to food cues rather than avoidance. High external eaters also rated the food stimuli as significantly more pleasant and reported increased desire to eat. Brignell et al. (2009) measured RT to food images while Johansson et al. (2004) used food words; it could be proposed that it is these methodological discrepancies which account for the contradictory findings. Brignell et al. (2009) also distinguished between trial performance for stimuli which were shown for 500 ms and 2000 ms. It was predicted that if attention was maintained towards food information on a VDP task, when the stimuli was shown for the 2000ms duration that this would be reflective of maintained attention. As 2000ms is a sufficient time for participants to divert their attention away from food stimuli if so desired. Biased processing was found at both of these stimuli durations (Brignell et al. 2009)

In 2009 Hepworth, Mogg, Brignell and Bradley explored how mood can influence VDP performance. Both stress and negative mood has been shown to influence FPB measured by the Stroop task (Rofey et al. 2004, Newman et al. 2008). Hepworth et al. (2009) findings revealed that negative mood was associated with faster responses to food cues at both 500ms and 2000ms durations. FPB was also found to positively correlate with external eating and dietary restraint. Negative mood was associated with elevated reported hunger. Adam and Epel (2007) outlined that negative mood (particularly stress) is associated with elevated cortisol release;

an indirect effect of this hormone is that it may increase the reward value of food cues. Subsequently this process may be what is behind the elevated attentional bias and craving illustrated in Hepworth's study (2009).

Recently Hou, Mogg, Bradley, Moss-Morris, Peveler and Roefs (2010) assessed the relationship between external eating, impulsivity and performance on the VDP. Attentional bias was positively correlated with both external eating (as measured by the DEBQ) but also trait measures of impulsivity (BIS/BAS scale/ Barratt impulsivity Scale). The relationship between impulsivity and attentional bias remained even after controlling for the co-variate of external eating. Although participants recruited for this study were of normal body weight; this is one of the first publications to provide evidence that individuals who are generally impulsive are more likely to allocate attention to cues associated with food reward than non impulsive individuals. It is worth noting that this study used two measures of impulsivity, but only the Barratt scale was found to be a significant correlate of FPB. This implies that only some aspects of impulsive behaviour may be likely to predict overeating. In this case inability to focus attention and motor impulsivity were related to problematic eating but not deficits in forward planning.

4.1.3 Distracter Tasks

An alternative approach to measuring how much attention is allocated to food based stimuli is to examine how distracting a stimulus is. When distracted, individuals ability to maintain focus on goal relevant information becomes diminished (Brooks et al. 2011). Personally relevant stimuli are more salient and are therefore more likely to capture our attention and lead to distraction. The visual search tasks are commonly used measures of distraction; the "odd-one out" task requires participants to find a target word or image amongst a matrix of distracting stimuli. In regards to appetite research the matrix contains either food distractors with a neutral target (distractor condition) or a food target hidden amongst neutral distractors (detection condition) (Hollit et al 2010). This task is useful within attention research as it allows assessment of whether attentional bias is reflective of enhanced orientation to food information (i.e. quick detection of food target when hidden among neutral distractors) or difficulty disengaging from food information (slow detection of neutral target if hidden amongst food distractors).

To date only two studies have used the visual search task to measure attentional bias to food cues. Smeets, Roefs, Furth and Jansen (2009) compared performance of individuals with eating disorders on visual search tasks which used both body and food words as targets. Participants had to identify if there was an "odd one out" in the matrix by stating yes or no, therefore measuring both accuracy and time taken to locate the target. Disordered eating was associated with increased detection of body stimuli and increased distraction from food stimuli. Participants with disordered eating did not display a rapid shift of attention to food based information however once the cue was successfully identified this group displayed difficulty disengaging their attention from the cue. However disordered eating was associated with heightened vigilance for body words but no deficit in disengagement from these cues.

Holitt, Kemps, Tiggerman, Smeets and Mills (2010) used a similar task to compare the performance of restrained and non restrained eaters on the visual search task. This study aimed to improve the paradigm used by Smeets et al. (2008) by asking participants to specify the location of the "odd one out". Findings revealed that restrained eaters demonstrated significantly enhanced orientation for food based information. However this group also had significantly higher speed of detection of neutral targets hidden amongst a neutral matrix. There was no evidence that restrained eaters were slower to disengage from food items. Holitt et al. (2010) work mirrors the response pattern that Smeets found for (2008) body words; Holitt et al. (2010) suggests that body words are highly salient for an individual with eating disorders therefore this is reflected in speeded detection of body words, however it can be proposed for the restrained eaters food words also have high salience as they are relevant to an individual's dieting goal. Both these studies propose that if a food or body word is salient for an individual they are likely to capture attention. The strong "attentional pull" of these stimuli makes it increasingly difficult for individuals to disengage their attention. Prolonged focusing of attention to these stimuli is likely to be reflected in difficultly regulating eating behaviour.

Another commonly used paradigm that is employed to study the ability of distracters to alter performance is the attentional blink. A typical blink task presents participants with a sequence of visual stimuli in rapid succession (appearing in the same spatial location on the screen); a participant's task is to identify the presence of a predefined target among the stream of images (Dux & Marois, 2009). It is hypothesised that when salient targets are embedded in a RSVP stream they may hinder the detection of other stimuli. Participants find it difficult to report the content of a second target (T2) if it is presented 200-500ms after target one (T1). The literatures interpretation is that the AB reflects competition between the two stimuli for attention resources. When the second target is a motivationally salient or emotional stimulus, the AB is much reduced. A recent publication entitled "All I could see was cake" used the attentional blink task to measure the distracting qualities of food stimuli in saited and hungry participants (Piech et al., 2010). In the RSVP streams displayed the content of target one (T1) was altered so that it contained either a picture of a food item, romantic scene or a neutral item. Participants were required to identify the orientation of the second target which was always a landscape. On trials where T1 was contained a food item, attentional capture increased which subsequently reduced accuracy of reporting the orientation of T2. These effects were amplified when participants were hungry, which again provides evidence that hunger heightens the vigilance for food based information.

4.1.4 Memory Tasks

FPB has also been measured using memory tasks, particularly those which look at recall or recognition (e.g. the number of food words remembered or the speed at which this information is recalled). Quicker or more accurate processing of food related information would be viewed as representing greater semantic processing of these items. Boon, Vogelzang and Jansen (2000) recorded the number of food stimuli that restrained eaters remembered from previous VDP task and stroop tasks. Restrained eaters did not respond significantly faster to food words on the visual attention task.. However in the subsequent recognition task restrained eaters were significantly quicker at recognising previously "seen" food words. Boon et al. 2000 suggests that this provides further support to claims that restrained eaters show increased approach to food words, but are able to exert cognitive coping mechanisms to compensate for their reactivity on attentional tasks. Israli and Steward (2001 as cited by Brooks et al. 2011) also examined memory bias in restrained eaters and unrestrained eaters, participants were asked to rate a list of "forbidden "food words for pleasantness. Restrained eaters remembered a significantly higher number of forbidden food words than those with low dietary restraint.

4.1.5 Attentional biases for food cues: where we are now.

Data on attentional bias for food cues is gradually emerging but the number of papers in this area remain small compared to the addiction field. Food related processing bias has been identified in restrained eaters (Hollitt, Kemps, Tiggemann, Smeets & Mills; Tapper et al. 2008), obese individuals (Castellanos et al., 2009; I. M. Nijs, Franken & Muris, 2010), external eaters (Brignell, Griffiths, Bradley, & Mogg, 2009; Newman, O'Connor & Conner, 2008) high chocolate cravers (Smeets, Roefs, & Jansen, 2009) and food deprived participants (Mogg et al., 1998; Piech, Pastorino, & Zald, 2010). These experiments provide considerable support for proposals that the attentional system has evolved to selectively attend to food information and that some individuals are hyper attentive to these cues. It is important to note that the actual measured differences in RT are often small (6-12 msec). The fact that all individuals shown some degree of bias for food information, suggests that FPB serves a function. It is likely that FPB serves to motivate eating behaviour as indices increase when participants are hungry (Castellanos et al. 2009; Mogg et al 1998; Tapper et al. 2010).

Indices of FPB are also higher when participants are responding to appetizing /palatable food cues (Hepworth et al. 2010; Tapper et al. 2010). This tendency to find high calorie food cues salient again reflects the competitive feeding environment of our evolutionally past. In this environment the quick detection of foods that had high calorie content enabled maintenance of energy stores. Tapper et al. (2010) found that satiated participants continued to be quicker at responding to appetizing food cues. This suggests that even when rewarding food cues have no biologically relevance they still are able to grab attention. This finding has important implications for overeating and weight gain particularly in populations who are hypersensitive to food cues.

A number of publications aimed to explore how behaviours associated with overeating correspond to measures of FPB. However it is worth noting that in all these studies published effect sizes are fairly small. The most explored relationship in this literature is that of the DEBQ measure of dietary restraint and FPB (Boon et al, 2000; Fadardi et al. 2011; Hollit et al. 2010 ; Paradeep et al. 2011; Pothos et al. 2008). However not all reports have supported predictions that FPB is elevated in individuals with high dietary restraint (Paradeep 2010) . Paradeep (2010) found no evidence of FPB on the stroop or VDP measures in obese individuals who had high

DEBQ_R scores. However it is worth noting that this group had a BMI range of 27-40 which is higher than what has been used by most other studies.

Work by Johansson et al. (2004) fuels an ongoing debate as to the extent that FPB reflect enhanced orientation towards cues or sustained attention (delayed disengagement) to food cues. Several authors have addressed this using eye tracking (Castellanos et al. 2009, Njis et a 2009; Wetherman et al. 2011). Castellanos et al. (2009) found that when fasted all participants spent longer looking at food items than non food items and had increased gaze to high calorie foods (Castellanos et al. 2009). However obese participants continued to increase their gaze towards food items when saited. Increased and prolonged gaze to food stimuli was replicated by Njis et al. (2009). Wetherman et al. 2011 suggested that gaze duration may be effected by bodyweight, as overweight participants were found to spend longer looking at food cues during initial gaze. However in regards to overall gaze, the obese group spent less time looking at food items than individuals of normal body weight. Tapper et al. (2010) has aimed to produce a behavioural measurement of orientation and disengagement. This is established by comparing RT to experimental picture pairs with neutrally matched pairs. This index is outlined in more detail in the methodological section of Experiment 2. Using this approach Tapper et al. (2010) found evidence for both delayed disengagement and increased orientation to food cues during a visual dot probe task. However analysis produced stronger evidence towards attentional bias being reflective of sustained attention (delayed disengagement) than increased orientation to food cues.

The degree to which FPB relates to weight gain vulnerability remains unclear. There is little consistent evidence to suggest that obese individuals display increased FPB or that this bias directly influences them to overeat. Conflicting findings may be a result of methodological differences such as the stimuli sets (words vs. images). A more general criticism is that there appears to be limited correlation between different measures of FPB. Pothos et al. (2008) found no correlation between indices of attention (stroop, visual probe, SRC); which suggests that different tasks may be measuring independent components of attention. This makes it difficult to extrapolate findings across methodologies and also to the general population.

There are also major discrepancies in the duration for which stimuli are shown during attentional tasks. This is particularly apparent within VDP research.

Cooper and Langton (2006) advocated that a major limitation of the paradigm is that published studies rarely investigate effects which emerge earlier than 500ms. This stimulus presentation time is commonly used with the VDP as it is assumed to represent an accurate measure of initial allocation of attention. This is based on findings by Bradley, Mogg and Millar, 2000 which showed that 500ms is when the first shift of attention and initial eye movements are made towards a stimulus (Bradley, Mogg and Millar, 2000 as cited by Cooper and Langton, 2006).Subsequently the majority of studies choose to present their stimulus pairs for this duration. However it has been suggest that even if 500 ms presentation time is sufficient to orientate attention a sufficient time period shift of to another stimulus (Posner and Peterson, 1990 as cited by Cooper and Langton, 2006). Therefore it can be proposed that the standard VDP only measures a snapshot of attention, and gives no insight into where attention is allocated overall (Cooper and Langton 2006). This methodological issue becomes particularly relevant in appetite research as it is difficult to get an untainted measure of attentional bias to food stimuli without accounting for cognitive strategies which may lead individuals to purposely divert their attention away from food stimuli (e.g. Johansson et al 2004).

Key Points:

- Methodological discrepancies in regards to stimuli duration may affect indices of FPB.
- Visual dot probe appears to be the most robust measure of FPB
- Does FPB indicate quicker orientation to food cues or delayed disengagement?
- Inconsistent findings in regards to the prediction that individuals with higher BMI would have greater FPB.
- Current literature has really only explored the role of external eating and dietary restraint (DEBQ_R) in FPB. How do other measures related to overeating correspond to FPB?
- To date there has been no published attempt to explore if FPB can manipulate participants to overeat in the laboratory environment.

Table 4.1 Methodological overview of key research publications exploring FPB

	Authors (Date)	Manipulation	Task Type	Stimuli	Stimuli Duration	Effect Size	Findings
1	Mogg et al (1998) N=32	Hunger	Visual Dot Probe	Words	500 ms 140 ms	$F(1,15)=10.36$ $p<0.01$	Hunger sig increased FPB at 500ms
2	Boon et al. 2000 N=59 Female only	Restraint (DBEQDEBQ)	Visual Dot Probe and Memory Recall	Words			No sig differences on dot probe task. Restrained eaters recalled more food words in recognition task
3	Johansson et al. (2004) N=43 Female only	External Eating (DBEQDEBQ)	Visual Dot Probe and Stroop	Words	500 ms	$t(41) = 2.55$ p =.014 Cohens 0.79	High external eaters were slower at responding to food words. Low external eaters had displayed FPB.
4	Pothos et al. 2008 N=224 Cross cultural	Restraint (DBEQDEBQ)	Stroop	Words	500 ms and 1250 ms	$F(2,213)=3.02$ $p=0.051$	Individuals with high dietary restraint who were not currently dieting showed significantly lower FPB than participants with similar levels of restraint but were currently on a diet
5	Newman et al. 2008 N=69	External Eating Stress	Stroop	Words	n/a	$F(1,60)=4.49$ $p<0.05$	Sig interaction between stress and FPB for snack words. High external eaters have greater FPB for snack words when stressed.

6	Brignell et al. 2009 N=55	External Eating DBEQDEBQ	Visual Dot Probe and SRC	Pictures	500 ms 200ms	$F(1,39) = 9.41$ $p <$ .01	External eating eaters showed enhanced FPB compared to low external eaters- hyper vigilance. No differences in SRC performance
7	Calitri et al. 2010 N=102	Longitudinal Study	Visual Dot Probe and Stroop	Words			Only stroop performance was predictive of BMI change over the 12 month period
8	Hepworth et al. 2010 N=80	Mood	Visual Dot probe	Pictures	500ms 2000ms	$F(1,77) = 5.57$ $p <$ .05	Negative mood resulted in faster RT at both durations to food items
9	Tapper et al. 2010 N=105	Hunger / food type	Visual Dot probe	Pictures	100, 500, 2000ms	Hunger correlates with appetizing FPB 100ms (r=.22, p<.05)	Hunger levels correlate with AB FPB for appetizing and bland foods; sustained attention rather than disengagement
10	Castellanos (2010) N=32	Obese vs. lean Fasted vs. Saited	Visual Dot probe plus eye tracking	Pictures	2000ms	Group $F(1,34)$=8.92, p <0.005. Interaction effect of group and satiety condition, $F(1,34)$=9.55, P<0.004	When hungry both groups increased gaze to food items, this was maintained in obese participants when satiated.
11	Njis (2010) N=66	Obese vs. lean	Visual Dot probe plus eye tracking	Pictures	100 ms 500ms	$F(1, 61) = 4.94$, $p <$ .05	FPB when hungry and saited in lean and obese participants on visual dot probeVDP. FPB was verging on sig differences between weight groups. No differences shown in regards to eye gaze

12	Hollit (2010) N=78	Restraint	Visual Search Task	Pictures	n/a	$F(1, 76) = 330.14$, $p < .001$	Enhanced orientation for food information in restrained eaters but also increased detection of neutral targets in neutral matrix. No evidence of differences in disengagement.
13	Hou et al. 2011 N=44	Impulsivity/external	Visual Dot Probe	Pictures	2000 ms	External r=0.36 p<0.05 Impulsivity r=0.42 p<0.05	FPB was found to be positively correlated with external eating (as measured by the DBEQDEBQ) and also trait measures of impulsivity (BIS/BAS scale)
14	Wetherman (2011) N=51	Obese vs. lean	Visual Dot probe plus eye tracking	Pictures			Overweight participants directed their first gaze more often toward food pictures than healthy-weight
15	Paradeep (2011)(Mogg and Bradley Group) N=26	Obese (High vs Low Restraint)	Visual Dot Probe and Stroop Plus Antagonist	Pictures and words	32ms		FPB displayed only in low restraint group, this was amplified by dopamine antagonist. No AB FPB in high restraint group.
16	Fadardi (2011) N=62	Dieting	Stroop (Combi)	Pictures and words			FPB significantly higher in dieters than non dieters.
17	Nummenmaa (2011) Experiment 1 N=53, Experiment 2 N=95	BMI	Visual Search Task	Pictures		Experiment 1 $F(2,52)$=13.78 p<0.001 r=-0.39 p=0.04, Experiment 2 r=-.40 p=0.05	Exp 1 food targets detected faster than non food targets. High BMI correlated with lower food detection advantage. Exp 2 when food images closely matched with neutral targets no differences in processing of targets. BMI still negatively correlated with food detection

4. 2 General overview of chapter's aims

Section 4.1 outlined the considerable body of work that has been conducted into FPB. From this review it can be predicted that being hyper attentive to food cues may promote overeating and subsequently increase BMI. Although there are a number of different approaches to measuring FPB the majority of publications have used the VDP (Brignell et al. 2009;Boon et al.2000; Caltri et al. 2010; Castellanos et al. 2010; Fadardi et al. 2011;Hepworth et al. 2010; Holliti et al. 2010; Hou et al. 2011; Johansson et al. 2004;Mogg et al. 1998; Njis et al. 2010; Nummenmma et al. 2011; Paradeep et al. 2011;Tapper et al. 2010). The VDP will be used in Chapter 4 to measure FPB; the two experiments in this chapter aim to address a number of limitations which have been raised from a review of the current FPB literature (i.e. inconsistent findings, methodological differences) (Section 4.1).

A central prediction of the literature is that individuals who are at risk of developing obesity will have highest indices of FPB. Research has shown that individuals with high dietary restraint (Boon et al, 2000; Fadardi et al. 2011; Hollit et al. 2010; Paradeep et al. 2011;Pothos et al. 2008) and high external eating (Brignell et al. 2009; Hou et al. 2011;Newman et al. 2008) have increased FPB. However at the time that this thesis was being developed there had been no published attempt to explore FPB in individuals who have high disinhibition. This oversight is particularly limiting as the TFEQ_D measure of disinhibited eating is consistently found to be the strongest predictor of BMI and overeating in laboratory settings(for review see Bryant, King and Blundell, 2007). Experiment 2 aims to explore whether individuals who have high TFEQ_D scores pay enhanced attention to food stimuli on the VDP.

Additionally Experiment 2 aims to incorporate the priming approach which has been used in the cue-reactivity literature (e.g. Schoenmakers, Wiers and Field, 2007). It is predicted that participants who are primed with the taste of chocolate prior to completing the VDP will display increased FPB. Priming is predicted to have a more pronounced effect on individuals whose behaviour is easily disinhibited in the presence of food cues (High TFEQ_D). A final aim of Experiment 2 was to explore the extent to which stimuli duration affects FPB. There remain discrepancies within the literature in regards to the extent to which FPB can be considered to reflect enhanced orientation to food cues or whether what the index is actually measuring is sustained attention.

The proposed relationship between attentional bias and obesity can only be substantiated by evidence which displays a direct link between FPB and overeating. However to date there have been no published attempts to explore the extent to which FPB can manipulate overeating. Therefore Experiment 3 aims to explore whether FPB can lead to overeating in a laboratory environment. Attentional retraining (learning to focus or avoid food stimuli on a modified VDP) will be used to manipulate the degree of attention participants pay to food cues. It is predicted that individuals who are trained to orientate their attention towards food stimuli will display increased FPB. If FPB is able to influence appetite behaviours a corresponding increased will be predicted in desire to eat, hunger and food intake

Experiment 2:

Exploring attentional bias in disinhibited eaters

4.2 Introduction to experiment 2

Experiment 2 aims to address a number of outstanding questions stemming from current FPB research (Section 4.1). FPB will be measured using a VDP task which will compare participant's reaction times to food images and neutral images (figure 1a).Corresponding it is predicted that participants will be quicker at responding to probes which replace food items. The VDP was designed so that the stimuli set could be categorised into appetizing (calorie dense) and bland (low calorie) items. This allows more detailed comparison of attention allocation based on calorie content. It is predicted that indices of FPB would increase in response to calorie dense stimuli. This experiment was designed to address five main aims:

1) Experiment 2 will explore if FPB is influenced by stimuli duration. Participants responses will be compared across trials where stimuli pairs are displayed for 100ms and 2000ms exposures. It is predicted that greater FPB will be found when stimuli are shown for 100ms, as this duration measures initial allocation of attention. If participants employ cognitive strategies to reduce their reactivity to food cues this is likely to be evident in decreased FPB for trials where picture pairs are shown for 2000ms..
2) Cue reactivity research has shown that a prime is able to elicit substance related thoughts and cognitions . For example work by Schoenmakers, Wiers and Field (2007) have shown that a priming dose of alcohol increased heavy drinkers reported craving and increased attentional bias to alcohol items on a VDP task. Schoenmarkers et al. (2007) study indicates that the priming may have a disinhibiting effect on behaviour. Subsequently reducing an individual's ability to exert cognitive control over their behaviour and therefore increases automatic responding. Experiment 2 will aim to establish if a priming dose of chocolate has the same effect on FPB. The prime itself will serve to manipulate participants into focusing on their food thoughts and cognitions which is likely to induce hyper vigilance for food related information. Half of the participants in this study will receive a hedonic food prime at baseline and

the other half will receive a control prime. If the disinhibition hypothesis is substantiated in this experiment, it can be predicted that the chocolate prime will have the most pronounced effect on the individuals who have high TFEQ_D scores.

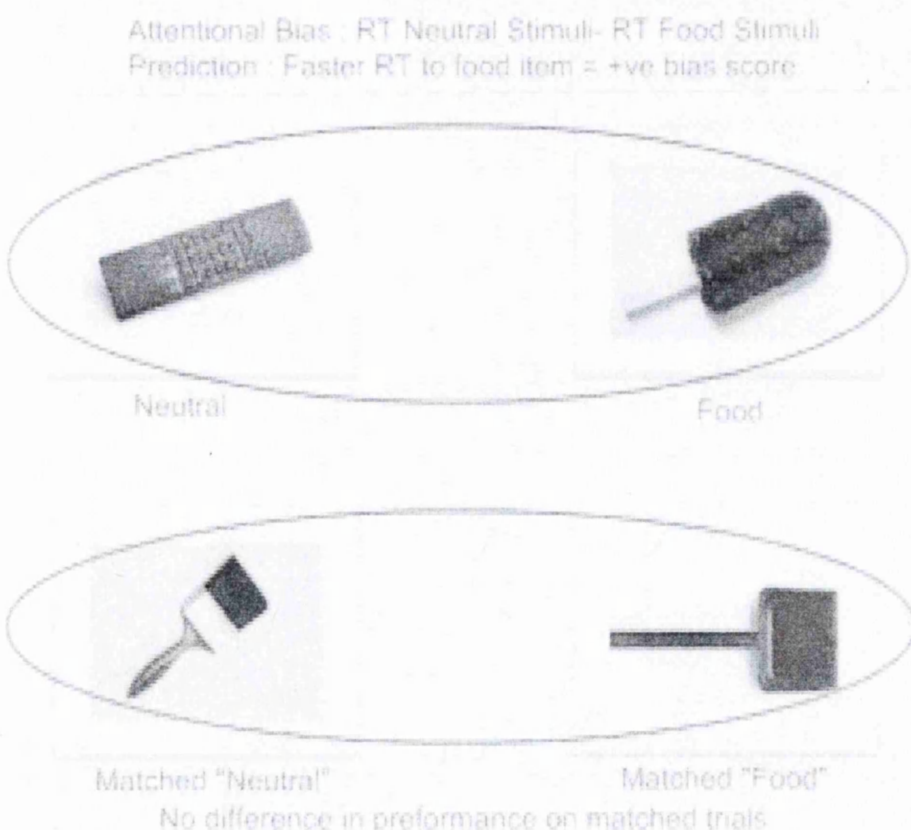
3) Additionally this experiment aims to establish if FPB reflects increased orientation to food cues or delayed disengagement. The VDP task used in will employ a "matched" pair design which has been used in a previous publication by Tapper et al. (2010). Alongside the usual experimental picture pairs (neutral vs. food item) the VDP will also include a "neutral-neutral" picture pairs. The content of which are closely matched to resemble the characteristics of each experimental picture pair. FPB may be the result of either quicker responses to food stimuli (increased orientation see Figure 4.1b) or a slower response to probes replacing neutral stimuli (disengagement see figure 4.1c) (Tapper et al. 2010). Therefore separate bias scores will be calculated to examine the extent to which FPB is underpinned by orientation or disengagement. No difference is predicted in regards to RT on the matched trials (Figure 4.1a).

4) The results of Experiment 1 showed that disinhibition is an important contributor to weight gain. In essence disinhibited eating depicts both a tendency to overeat when presented with highly palatable foods but also inclination to eat opportunistically when in an environment where food cues are abundant (Bryant et al. 2007).Individuals who score highly on TFEQ-D scales have consistently been found to have high body weight (Boschi et al 2001; Provencher et al. 2003), make unhealthy food choices (Contento, Zybert, & Williams, 2005; Lahteenmaki & Tuorila, 1995) , increase food intake during experiments (Lawson et al. 2005) and experienced reduced success from weight loss interventions (Bryant, Caudwell, Hopkins, King and Blundell 2012). High TFEQ_D scores are also predictive of long term weight gain in older adults (Hays et al. 2002). At the time this thesis was developed there had been no published experiments examining attentional bias in individuals with high TFEQ_D scores. Therefore this study will specifically explore the extent to which high disinhibition is reflective FPB on the VDP task. It is predicted that

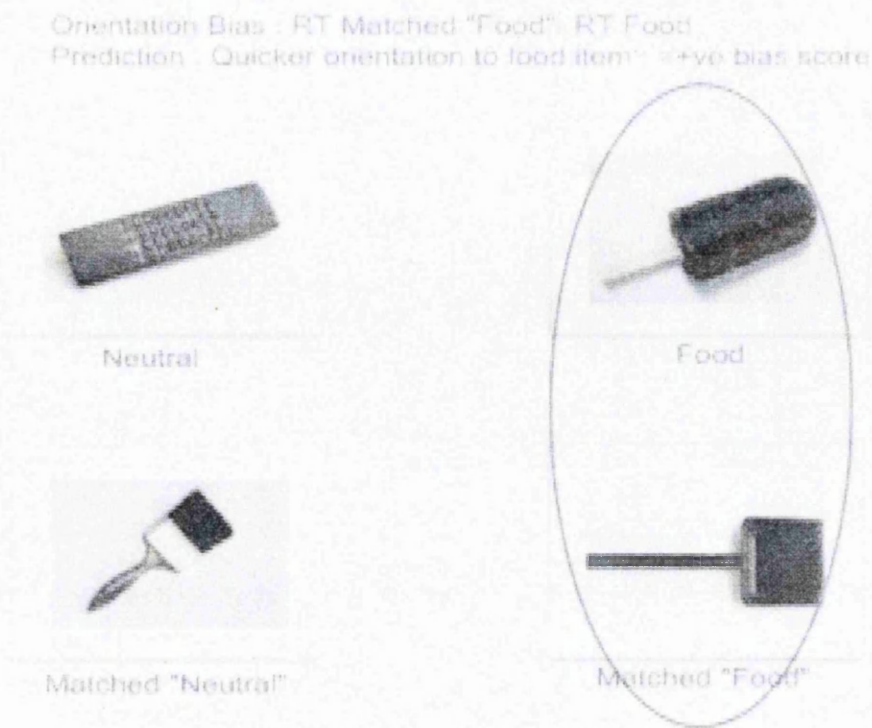
disinhibited eaters will display elevated FPB and that individuals scoring high on the TFEQ_D will be more pronouncedly influenced by the priming manipulation outlined above. However if individuals who score highly on the TFEQ_D use cognitive strategies to reduce the impact of food cues on their behaviour it is likely that these will be reflected in slower response times to food stimuli at 2000ms.

Finally this experiment will additionally collect data from a number of appetite measures (i.e. TFEQ, DEBQ, and PFS). This will allow exploration of how these may influence the amount of attention that an individual pays to food cues in the environment.

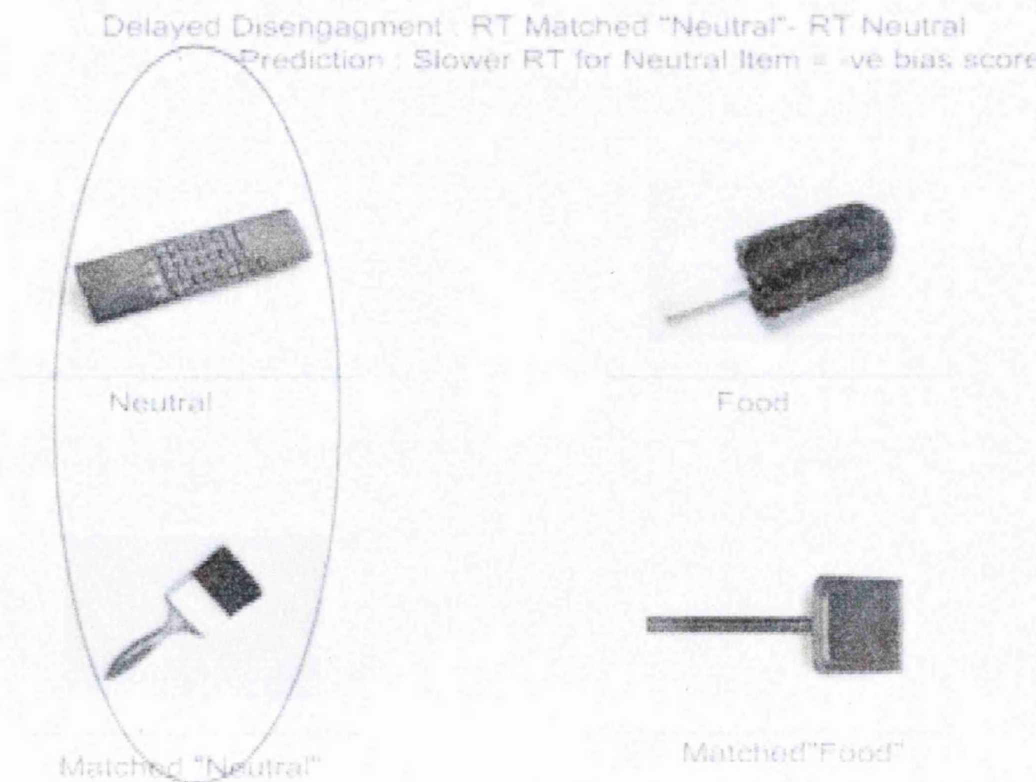
Figure 4.1:



A) Pictorial example of how food processing bias scores were calculated



B): Pictorial example of how orientation bias to food cues was calculated



C) Pictorial example of how delayed disengagement was calculated

4.2.1 Methods

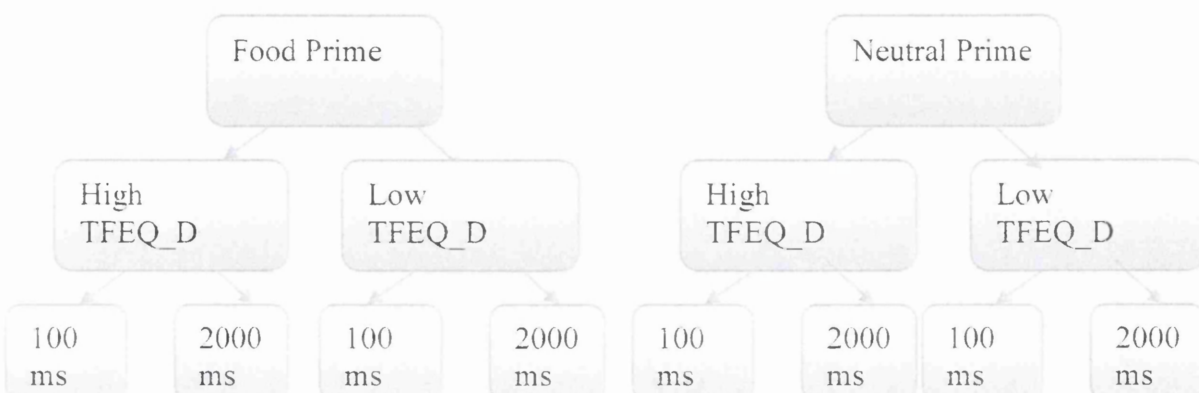
4.2.1.1 Participants

Participant recruitment adhered to the selection criteria outlined in the general methodology section. Recruitment targeted individuals who scored in the bottom or top 40% of the TFEQ_D (Stunkard and Melleck, 1985). Participants were unaware that they would be taking part in a study that was measuring attentional bias to food stimuli and were instead recruited under the guise of study that examined the effect of mood on reaction times. Forty five participants (35 Female and 10 Male) took part in this experiment; 23 of which were classified as low disinhibited eater and 22 high disinhibited eaters. Twenty three participants were primed with chocolate prior to testing and the remaining twenty two received a control prime. The mean age of participants was 20.46 ±1.78 years and mean BMI was 23.60± 4.82..

4.2.1.2 Design

This study used a 2 x 2 x 2 mixed design to access the effect of disinhibited eating, priming and stimuli presentation time on attentional bias for food stimuli (Figure 4.2). The between subjects IV of prime had two levels (food prime vs. control prime). Each priming group was made up of high and low TFEQ_D scores; therefore the between subjects IV of disinhibited eating also had two levels (high vs. low TFEQ_D scores). All participants completed a VDP task which showed stimuli for 100ms and 200ms, therefore the within subjects IV also had two levels (100ms vs. 2000ms).

Figure 4.2:



Experimental Design

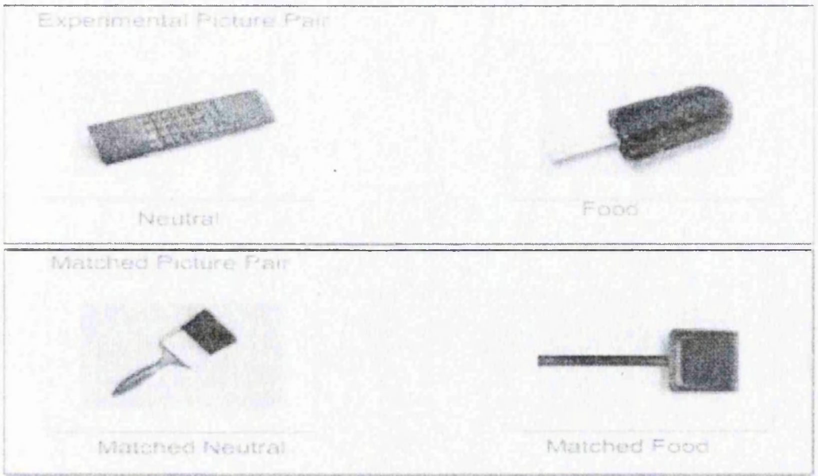
4.2.1.3 Stimulus Materials and Equipment

Visual Dot Probe Task

The stimuli used in the visual dot probe task consistent of 128 colour photographs (Appendix K). There were 32 food images which were categorised into 16 calorie dense foods (sweet and savoury e.g. chocolate buttons, pizza) and 16 low calorie foods (apples, lentils). These were matched with 32 household (neutral) items. Picture pairs were matched in regards to visual characteristics, image complexity approximate shape and jpeg size. A further 32 household items were used to create the neutral-neutral pairs. These pairs contained two household items which closely resembled the main visual characteristics of a corresponding experimental pair. All stimuli used in this task had been previously rated in a pilot study as being representative of each of the two categories (Tapper et al. 2009). An example of experimental and corresponding neutral-neutral pair can be seen in Figure 4.3. In addition 10 animal items were used to create practice trials.

The task was run using E-prime; participants were seated at a desk 100cm from the monitor. Each trial commenced with a fixation cross displayed for 100 ms in the centre of the screen. The cross was followed by the presentation of a pair of pictures side by side for either 100 ms or 2000ms. A probe was then presented in the position of one of the preceding pictures pairs until participants gave a manual response to the probes position. Participants pressed one of two buttons to indicate the identity of the probe. Participants were allowed a short break between the presentations of the two trial blocks. The presentation of the trial blocks was counter balanced, with all trial presented in a random order. There were 10 practice trials and two blocks of 258 trials (128 critical trials, 128 matched neutral trials). All trials were made up of 4 presentations of each of the experimental or matched neutral picture pairs (e.g. experimental stimulus shown on left followed by probe on left, experimental stimulus on left followed by probe on right, experimental stimulus shown on right followed by probe on right and experimental stimulus show on right followed by probe on left). These presentations were counterbalanced. When presented on screen, each stimulus was 5cm high by 5cm wide. There was a distance of 6 cm between the fixation cross at the centre of each image.

Figure 4.3



A representational diagram of experimental and matched neutral trails on the VDP task

Ratings Task

All stimuli used during the VDP task were included in this rating task. These pictures were presented one at a time in the centre of the screen for 2000ms. After each picture there was a pause of 500ms followed by a 5 point rating scale, which was displayed until response. The response scale ranged from 1 (very unpleasant) to 5(very pleasant).

Prime

The food prime was a miniature, individually wrapped Cadbury dairy milk bar (55 cal and 3.2 g of fat). When consuming the prime, participants were required to complete set of VAS ratings for a number of attributes (Appendix H). These included pleasantness, intensity of flavour and richness (e.g. How rich was the chocolate....). The control prime used in for this research was a 9cm X 6cm image of Monets "Lilly Pads". Similarly participants were required to rate the control prime by completing VAS ratings for pleasantness, intensity of colour and richness of detail. The scale was designed to be closely matched to the chocolate tasting scale to reduce demand characteristics. (Appendix H)

Questionnaire Measures

All questionnaire measures of eating behaviour were completed online prior to attendance in the laboratory using a web based screening questionnaire. This also collected demographic information, along with measurements of current weight, height and heaviest ever weight. Participants completed the TEFQ (Stunkard and Messick, 1985), DEBQ (Van Strien et al. 1986), PFS (Lowe et al. 2008) and the BIS and BAS_rr subscales from the BIS/BAS questionnaire. Baseline responses were measured using the mood questionnaire (outlined in the general methodology) (Appendix G). Participants completed the mood questionnaire at 2 time points during the study (on arrival and at debrief)

4.2.1.4 Procedure

Written informed consent was obtained prior to the commencement of the study. All participants completed an online questionnaire prior to their attendance in the social laboratory (TFEQ_D). TFEQ-D scores were used to formulate experimental and control groups, highly disinhibited eaters were those who's scores ranged between 7 and 14, while low disinhibited eaters were participants who scored between 1 and 6.

On arrival in the social laboratory participants were required to rate their hunger they were then given either a food prime or control prime which they were instructed to look at (or consume). Participants were told to concentrate on the thoughts and feelings the prime was generating. They then completed a short questionnaire assessing a number of properties of the prime (e.g. attractiveness, desirability).

Participants were then introduced to the VDP and were informed that they would be required to attend and respond to stimuli in the form of pictures. Participants were told that the task was measuring their cognitive performance and therefore it was essential that they responded to each trial as quickly as they could. After the VDP task participants completed stimuli ratings. The stimuli rating task was also presented using e prime; it required participants to rate the attractiveness of all of the stimuli presented during the VDP task.. At the end of the computer tasks participants rated current hunger. All participants were fully debriefed. On average the laboratory session lasted for duration of 45 minutes.

4.2.2 Analysis and data handling

Kolmogorov-Smirnov and Shapiro Wilk tests showed that the dependent variables of interest were normally distributed. These variables included RT on the dot probe task, hunger ratings, pleasantness ratings and all demographic data (BMI scores, DEBQ scores).

Treatment of outliers followed a two stage process in accordance with previous literature (Tapper et al. 2009). First errors were excluded on an individual trial level (for individual RT scores). Trials with errors or trials with RT <200ms and >2000 ms were removed. A total of 0.28% of the data was removed in this way. Congruent trials where those in which the probe replaced the food picture and incongruent trials were when the probe replaced the neutral picture. For each of the VDP tasks, Mean RT (and SD) was calculated for 8 trial types (e.g. calorie dense congruent, calorie dense incongruent, calorie dense matched neutral congruent, and calorie dense matched neutral incongruent). Outliers were excluded in relation to trial types mean bias scores (outliers reflect atypical influences at the participant level). No outliers were found for this data set. An FPB score was calculated each food types (high calorie, low calorie) across both exposure times (100ms and 2000ms). This was done by subtracting mean RT for congruent trials from the mean RT for incongruent trials. Thus a positive FPB would be viewed as a bias favouring food pictures relative to control stimuli.

In line with a previous publication by Tapper et al. (2009) the matched neutral data was used to establish where participants allocated attention during the task . Orientation scores were calculated, by subtracting the RT for matched food trials from the RT for matched neutral trials (e.g. high calorie congruent 100ms from high calorie matched neutral congruent, 100ms). This created 4 orientation bias scores (high calorie 100 ms, high calorie 2000ms, low calorie 100ms, low calorie 2000ms). A positive bias value indicated that participants were quicker at orientating their attention to the food item in comparison to the matched neutral item. Disengagement bias scores were calculated by subtracting the RT for neutral trials from the RT from matched neutral trials. A negative bias value indicated that participants were slower to disengage from the item on the experimental trials.

The main dependent measure of interest was food processing bias this was calculate using the above criteria. Other dependant variables included hunger rating (at baseline and post experiment) this was a scale that ranged from 0-100mm.

Participant's demographic characteristics were contrasted between the two groups using independent t-tests. These were used to explore group differences in TFEQ, DEBQ, PFS scores along with current BMI and heaviest BMI. Participants rated their hunger at baseline and following the visual probe task; differences in these ratings were assessed across time points (paired t-tests) and between the two groups (independent t-tests).

The main hypothesis was assessed using a mixed design 2 x 2 x 2 x 2 analysis of variance (ANOVA) with stimulus duration (100ms and 200ms) and food category (high calorie and low calorie) as within subjects factors. TFEQ_D group (high vs. low) and Prime (food vs. control) were between subjects factors. The DV was FPB. Mauchly's test indicates that the assumption of sphericity was upheld for all main factors therefore a corrected *F* value will not be reported. Planned comparisons were carried out for all significant factors (simple contrasts, first/last).

The same ANOVA set up was used to examine differences in RT between matched neutral trials. Accuracy across the two tasks was compared using an ANOVA. This had a within subjects factor of task (100ms and 2000ms) and the between subject factors of TFEQ_D group and Prime. The DV was percentage accuracy. Group differences in orientation and disengagement were compared for each trial type using independent t-tests.

Spearman's correlations were conducted to establish the relationship between orientation/disengagement bias, BMI and measures of eating behaviour. Unless stated the reported *p* value is relevant to two tailed probability. Spearman's correlations were used examine the relationship between FPB across the whole sample (averaged across picture duration) and each psychometric measure. Finally differences in rated preference of stimuli were assessed using mixed 3 x 2 x 2 ANOVA with item type (High calorie vs. low calorie vs. object) as a within subject factor. TFEQ_D group and prime were between subject's factors. The DV was rated pleasantness. Throughout the ANVOA results were checked for possible violations of sphericity and where applicable the greenhouse-geisser adjustment was applied.

4.2.3 Results

4.2.3.1 Demographic data

Participants were allocated into groups based on their scores on the TFEQ measure of disinhibited eating. Participants who scored less than 5 on the TFEQ_D were classified as low disinhibition and those that scored higher than 7 as high disinhibition. The low disinhibition group contained 23 participants and the high group 22.Mean demographic data of the two groups is shown in Table 4.2.

Independent tests were used to examine if the groups were matched in regards to demographic characteristics. As expected, the two groups differed significantly in terms of their TFEQ_D scores [t (43)-8.55=p=0.00]. The two groups also different significantly in terms of dietary restraint as measured by the TFEQ _R [t (43) =-2.290 p =0.027] and DEBQ_R [t (43) =-2.150 p =0.037]. The high TFEQ_D group had had significantly higher trait hunger as measured by the TFEQ_H [t (43)=-2.147 p =0.037] and total PFS scores [t(43)=-3.587 p =0.001].The groups did not significantly differ in terms of external eating [t (43)=-0.914 p =0.366].

The differences in eating style indicate that the high TFEQ_D group may be more vulnerable to weight gain. This is also reflected in the fact that the high TFEQ_D group had significantly higher current BMI [t (43)=-2.009 p =0.051 one tailed =0.025]. However the groups did not differ on self report of heaviest ever BMI [t(43) =-0.048 p =0.962].

Table 4.2:

	Group	**Low TFEQ_D** ***N*=23**	**High TFEQ_D** ***N*=22**
	Age	20.65± 2.33	20.27±0.94
*	BMI	22.24±4.52	25.03±4.79
	Heaviest BMI	25.79±16.36	25.97±5.62
	Sex (female: male)	16:7	19:3
*	TFEQ_D	4.22±1.41	9.37±2.49
	TFEQ_R	4.17±4.62	8.09±6.71
	TFEQ_H	5.04±3.19	7.27±3.76
	DEBQ_R	1.50±0.66	2.02±0.95
	DEBQ_Ex	2.94±0.57	3.16±0.85
	DEBQ_Ex	2.01±0.57	2.78±0.84
	Total PFS	42.22±14.21	58.95±17.022
	BIS	18.56±3.16	18.00±4.39
	Bas_RR	20.83±1.95	21.30±2.105

Mean (± SD) demographics of TFEQ_D groups

*indicates significant group differences P<0.05

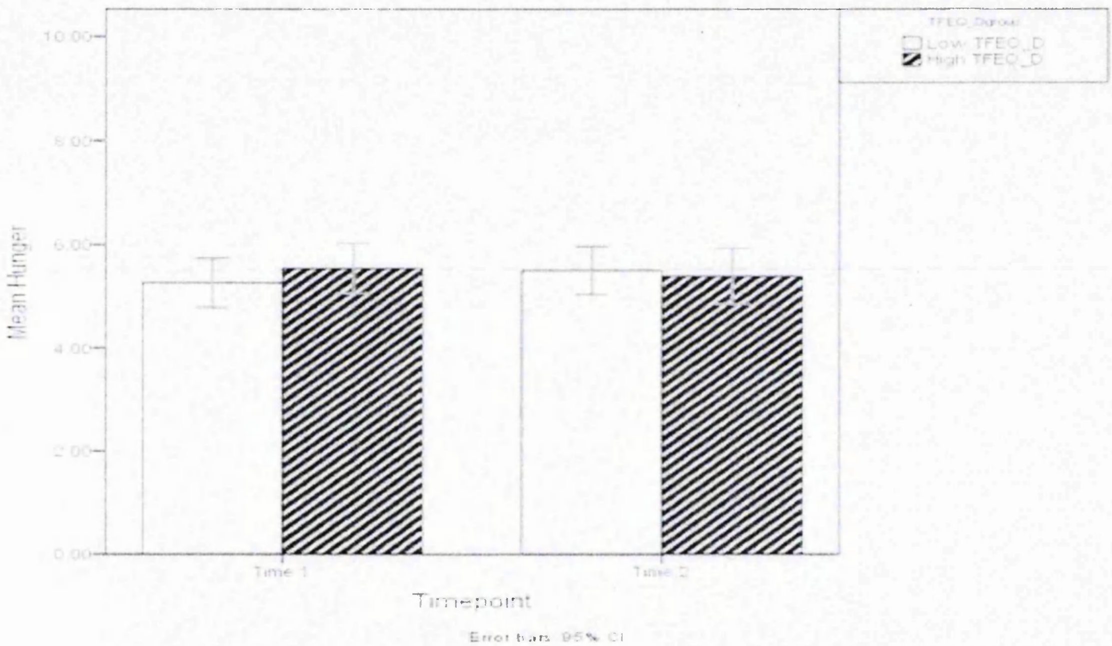
4.2.3.2 Hunger ratings

VDP did not influence hunger in either group

Participants rated their hunger at baseline and at the end of the VDP task. These ratings revealed that participants were moderately hungry at baseline [Hunger

T1 Mean±SD low TFEQ_D 52.61±2.29, High TFEQ_D 55.45±2.35] (Figure 4.4). Although hunger was rated as being slightly higher in the high TFEQ_D, no significant group difference were found between baseline hunger ratings [$t(43)$=-.0.869 p =0.390]. Hunger ratings remained consistent across the testing session [Hunger T2: Mean±SD low TFEQ_D 55.04±2.23, High TFEQ_D 53.91±2.60]. There were no group differences in rated hunger at time two [t (43) =0.332 p =0.742]. No significant increase in rated hunger was found between time point one and two [$t(43)$=-.392 p =0.697].

Figure 4.4:



Mean ±SE rated hunger at time 1(baseline) and time 2 (following training) for the high and low TFEQ_D groups

4.2.3.3 Findings from the VDP

FPB scores were calculated across each condition and exposure duration. The mean FPB for each of the two TFEQ-D groups are shown in Table 4.3. A mixed design ANOVA was conducted to ascertain if TFEQ_D, prime, stimuli duration or calorie content influenced indices of FPB (outlined in section 4.2.2). The main findings of this analysis are discussed below.

Table 4.3:

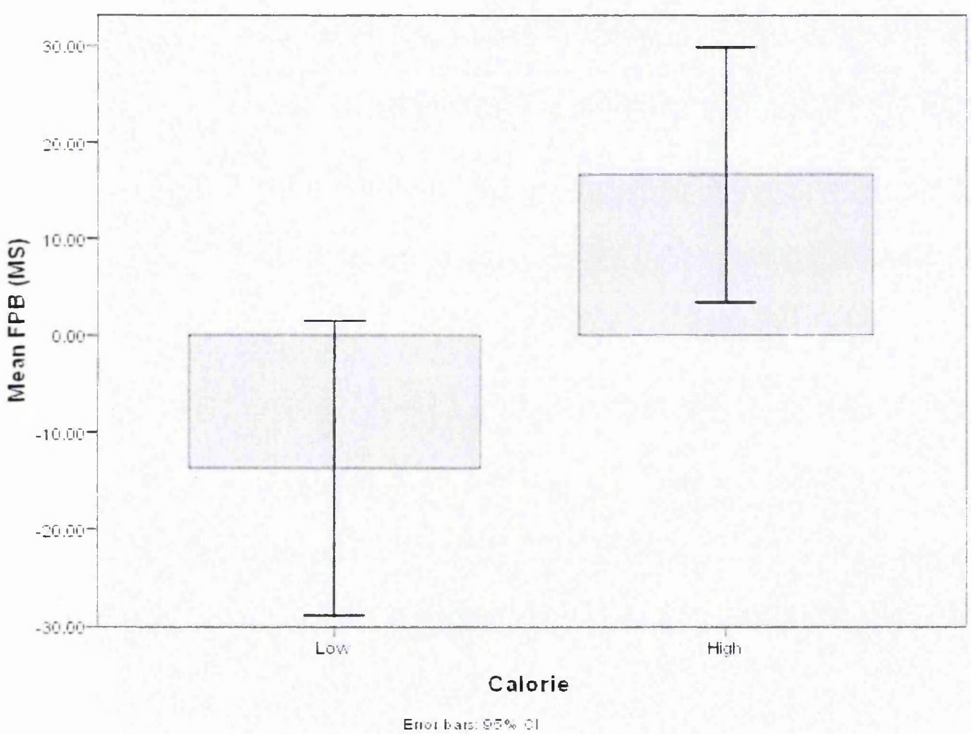
Group		High Calorie	Low Calorie
Low TFEQ_D	100ms	17.88±57.41	-20.088±76.46
	2000ms	8.206±75.48	9.01±58.11
High TFEQ_D	100ms	19.80±40.59	-10.99±49.03
	2000ms	20.95±73.41	-33.42±76.76

Mean (± SD) FPB for each stimuli exposure and trial duration

FPB was greatest for high calorie foods.

Analysis revealed a significant main effect of calorie content [F (1, 41) =69.952 p =0.00] (Figure 4.5). Planned contrasts revealed that attention was biased towards high calorie food items. However indices of FPB for low calorie items were negative, indicating that participants were quicker at responding to probes which replaced neutral items on trials which contained low calorie foods. .

Figure 4.5

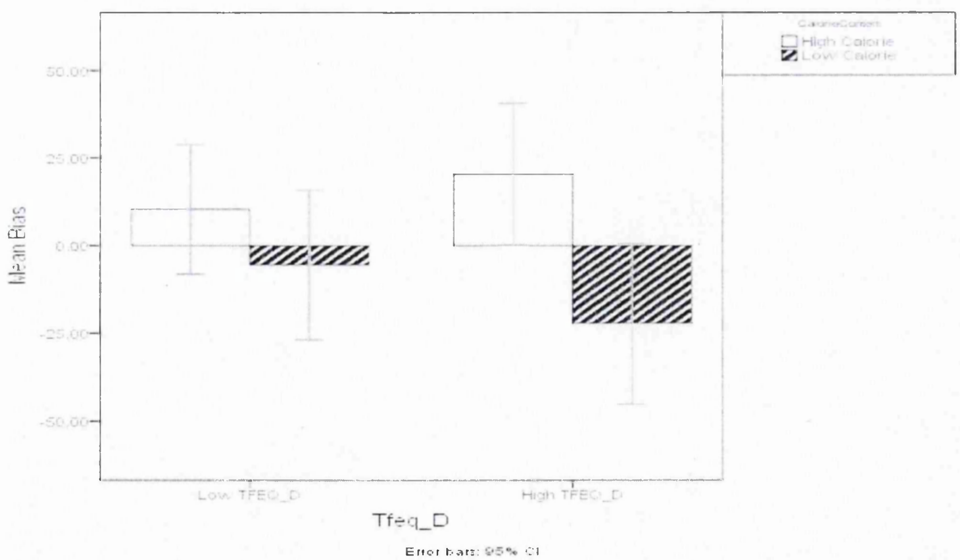


Differences in mean FPB in response to high and low calorie food items on the VDP task

Individuals with high TFEQ_D had elevated FPB for high calorie foods.

Although the ANOVA revealed no significant main effect of TFEQ_D group [F (1, 41)=0.124 p =0.727].There was a significant interaction between TFEQ_D and food category [F(1,41)=12.506 p =0.001]. This is shown in Figure 4.6. Mean FPB score (average FPB from 100ms and 2000ms VDP) were calculated for high calorie items and low calorie items. These were used to explore the interaction between calorie content and TFEQ_D group. Both groups displayed FPB only for trials containing high calorie items. For both groups calculated FPB for high calorie items was significantly higher than the FPB for low calorie items (low TFEQ_D group [t (22) =3.686 p =0.001 effect size =0.62; high TFEQ_D group [t(21)=8.113 p =0.000 effect size= 0.87] . The effect size was largest for the high TFEQ_D group. This was also the group that displayed greatest mean FPB towards high calorie food items [M 20.39±9.74 compared to M 13.04±8.98].

Figure 4.6:



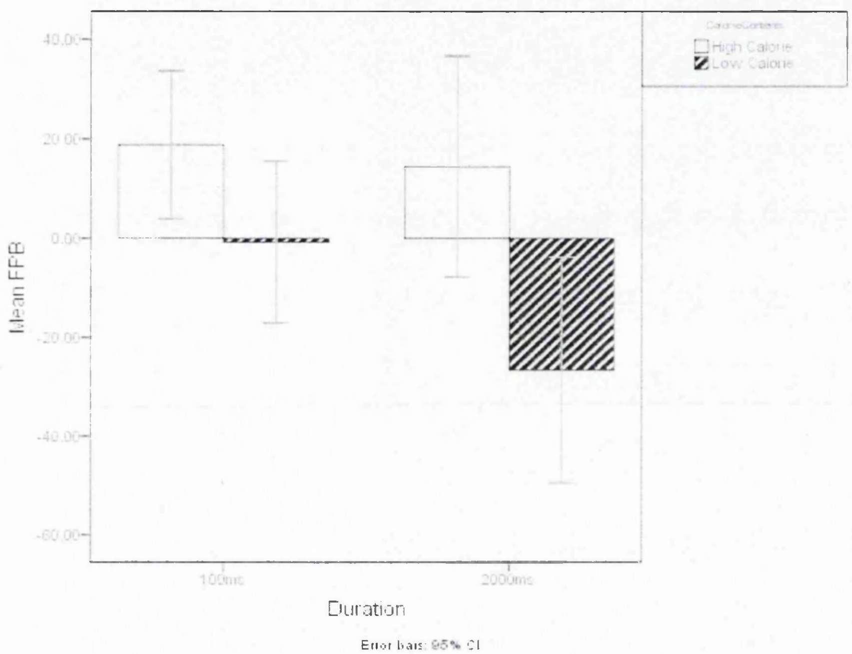
Interaction between TFEQ_D group and calorie content on FPB

Only FPB for low calorie foods was influenced by stimuli duration

Analysis revealed no significant differences in overall FPB on the 100ms and 2000ms VDP tasks [F (1, 42) =1.861 p=0.180]. However a significant interaction was found between stimuli exposure and calorie content [F (1, 42) = 7.463 p =0.009].

This was explored using paired sample t-tests these revealed no significant differences in FPB for high calorie items at 100ms and 2000ms [t (44) =.328 p =0.744]. For low calorie foods FPB scores indicated a processing bias in favor of neutral items, this bias was significantly lower at 2000ms than 100ms [t (44) 2.037 p =0.048]. This indicates that when participants had longer to process low calorie stimuli on the VDP they were quicker at responding to neutral items. [Figure 4.7].

Figure 4.7

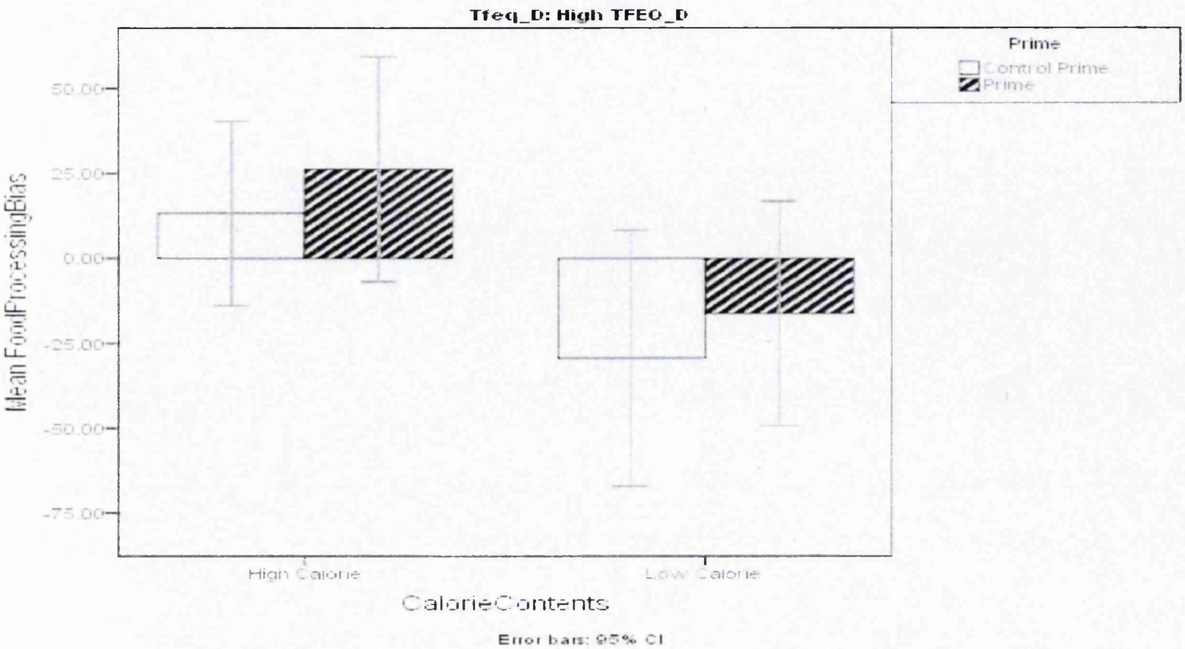


Interaction between stimuli duration and calorie content on FPB

Trend towards priming increasing FPB

Although the effect of Prime was not found to be significant [F (1, 41) =0.082 p=0.776]. Figure 48 indicates a trend towards priming having an increased effect on FPB in the high TFEQ_D group. However the presence of the prime only appeared to influence RT for high calorie foods.

Figure 4.8



(a) The effect of Priming on FPB on the high TFEQ_D group

(b) The effect of Priming on FPB on the low TFEQ_D group

FPB is a poor predictor of BMI

Spearman's correlations were conducted to establish if there was a relationship between FPB and BMI. In regards to task performance the only significant predictor of BMI was FPB for low calorie items on the 2000ms task. However this relationship was weak [r=0.309] and significant only at one tailed probability. Heaviest ever reported BMI was found to positively correlate with the FPB on the 2000ms task [High calorie, r=0.306 and low calorie r=0.321]. BMI was also found to positively correlate with disinhibited eating [r=0.327 p =0.028] and heaviest ever BMI [r=0.775 p =0.00]. This demonstrates that the high disinhibited eating group were likely to be those which had heaviest current body weight and had been overweight in the past.

FPB may also be mediated by Reward Responsivity

Reward responsively as measured by the BAS_RR was found to negatively correlate with FPB for low calorie items [r=-.275 p =0.037] and high calorie items [r=-.308 p =0.022]. Both of these relationships were weak and significant only to one tailed probability. To further explore the relationship between reward responsivity and FPB. A median split was conducted to categorise participants into two groups based on their BIS_RR scores. Independent t-tests were conducted to compare performance of individuals who were classified as high or low reward responsive for each TFEQ_D group. For the low TFEQ_D group reward responsively did not affect FPB for high or low calorie items [high calorie items t(21)=0.217 p =0.830; low calorie items t(21)=0.286 p =0.776].

For the high TFEQ_D group there was a significant difference in RT for high calorie items [t(18)=2.333 p =0.031]. The mean data indicates that for the high TFEQ_D group low reward responsively was associated with increased attentional bias to high calorie food items (Mean : 98.43±17.28). However the means FPB for participants who had high TFEQ_D and High BIS_RR was negative. This indicates these individuals were slower at responding to food items in the picture pairs (Mean =-3.2486±0.79). A significant difference was also found in regards to attentional bias for low calorie items. [t (18) =2.262 p=0.036]. Although neither the high or low BIS_RR scores were reflected in attentional bias for low calorie food items, individuals who were highly reward responsive were significantly slower at responding to food items.

In regards to stimuli duration, when high disinhibited eaters who were also highly responsive to reward were shown food stimuli for 2000ms they were significantly quicker at responding to objects [t (18)=1.995 p =0.061 one tailed p =0.0305]. The low reward responsive group displayed attentional bias towards food items at this duration. There was a trend towards the same pattern at 100ms [t(18)=1.737 p =0.100 one tailed p =0.05].

No differences in RTs on matched neutral trials.

No significant differences in RT were found for probes in the matched neutral trials. There was no main effect of stimuli duration [F (1, 40) 1.98 p=.170], TFEQ_D [F (1, 40) =0.992 p =0.343] or prime [F (1, 40)1.213 p =0.277]. No significant interactions were found [p >0.05]

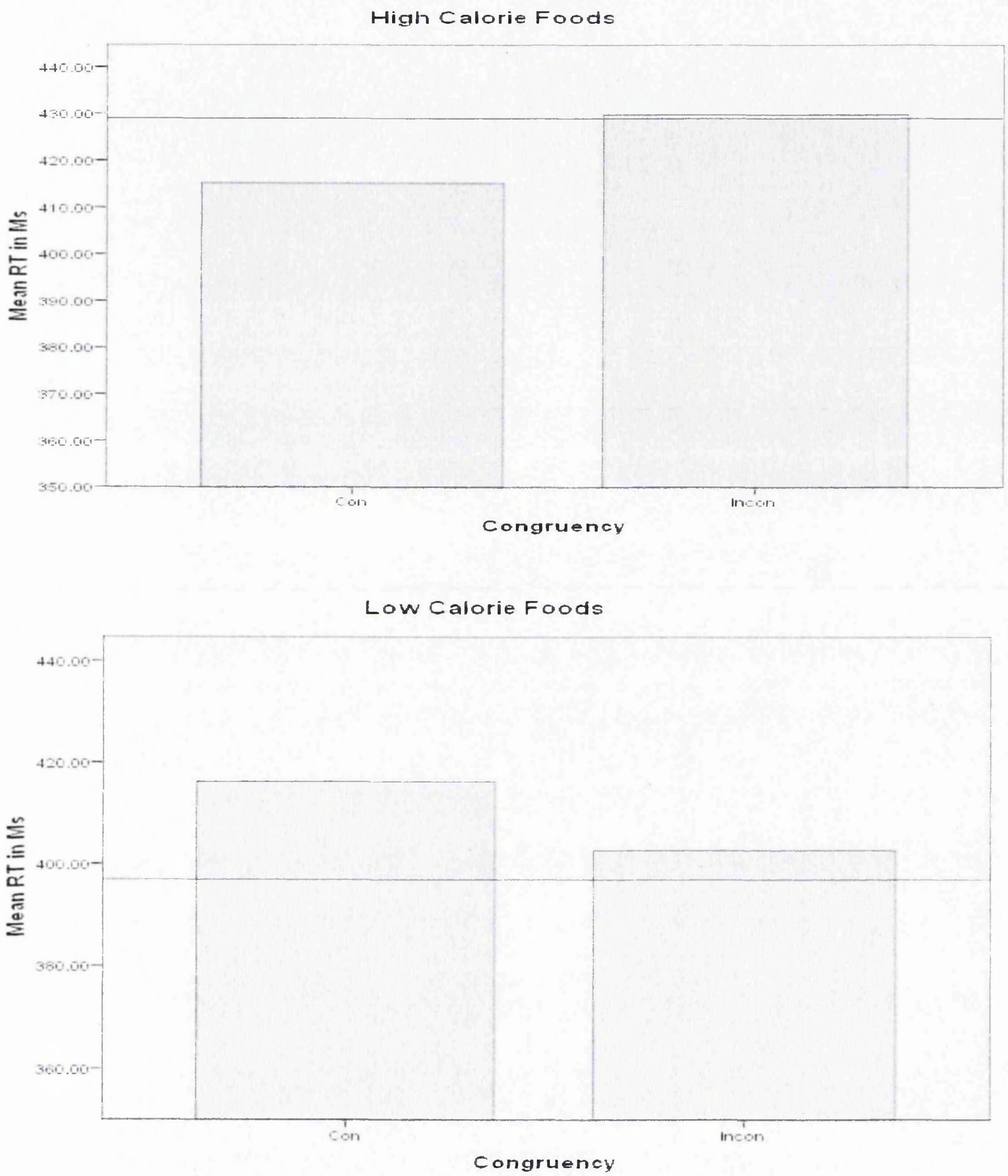
Stimuli duration influenced probe detection accuracy.

Participants were more accurate at responding to probes displayed for 2000ms than 100ms [F (1, 41) =240.705 p =0.000]. Despite this effect accuracy remained high across both tasks [Mean 99.6% (2000 ms) compared to 96.5% (100 ms)]. Task accuracy was not influenced by TFEQ_D [F (1, 41) =0.244 p =0.624] prime [F (1, 41) =0.198 p=0.673] or calorie content [F (1, 41) =0.244 p =0.624].

4.2.3.4 Evidence of Orientation and Disengagement on the VDP

The extent to which FPB reflected increased orientation to food cues or delayed disengagement was explored using an approach set out by Koster et al (2004). RTs (ms) for congruent and incongruent trials were compared to mean RTs from neutral trials to whether FPB reflected vigilance or disengagement. If participants had increased orientation to food cues this would be reflected by quicker responses on congruent trials (compared to neutral), whereas difficulty disengaging from food cues would result in slower responses on incongruent trials (compared to neutral). Evidence of increased orientation to food cues was only found for high calorie items, here participants were significantly faster at identifying probes replacing congruent food items compared to neutral items [t (45) =-1.79 p=0.039]. FPB did not appear to reflect delayed disengagement in either trial type; responses on incongruent trials were not significantly slower than responses to neutral trials [p>0.05]. This pattern of RTs is depicted in Figure 4.9

Figure 4.9



Mean RTs (in ms) on congruent and incongruent High Calorie- Neutral and Low Calorie –Neutral trial types, compared to RTs on the Neutral-Neutral trials (horizontal line).

4.2.3.5 Pleasantness Ratings of Stimuli

Table 4.4

	Low Calorie	High Calorie	Objects
Low TFEQ_D	3.34±0.12	3.54±0.12	3.01±0.05
High TFEQ_D	3.37±0.07	3.83±0.12	3.02±0.06

Mean±SD rated pleasantness of stimuli on dot probe task

High Calorie food stimuli were rated as most pleasant

All participants rated the pleasantness of stimuli used in the VDP task. Mean (±SD) ratings shown in Table 4.5. A mixed design ANOVA was conducted to ascertain if calorie content prime or TFEQ_D influenced pleasantness ratings. Analysis revealed that there was a significant main effect of picture type [F (2, 82) 38.440 p =0.000] Simple contrasts indicated that low calorie items were rated as more pleasant than neutral objects [F(1,41)-26.504 p =0.00]. High calorie foods were rated as being significantly more pleasant than neutral objects [F(1,41)=68.120 p =0.00] and low calorie foods [F(1,41)=16.717 p =0.00]. Mean pleasantness ratings did not correlate with FPB [p >0.05]. The chocolate prime did not influence stimuli ratings [F(1,41) =0.946 p =0.336] and there were no differences in TFEQ_D group ratings [F(1,41)=1.482 p =0.230].

4.2.3 Discussion

The data collected generally supports the overall prediction that trait disinhibition (as measured by the TFEQ_D subscale) is associated with increased FPB. An interaction was found between TFEQ-D and calorie content of the food item on the VDP. Although both TFEQ_D groups were significantly faster at responding to probes which replaced high calorie food items. Greatest FPB found for the high disinhibition group. The largest effect sizes were seen for this group. Neither group were significantly faster at responding to low calorie items compared to neutral items.

These findings are consistent with the proposal that FPB is elevated for palatable food items (Hepworth et al. 2010; Tapper et al. 2010). Both groups were found to be significantly quicker at reacting to probes replacing high calorie food items. This finding is unsurprising as it is likely that we have evolved to be hyper attentive to cues that signal food availability. The higher FPB for high calorie foods seen in disinhibited eaters supports predictions that overeating may be underpinned by hypersensitivity to food cues.

High calorie stimuli were rated as being significantly more pleasant compared to the other stimuli. This indicates that salient food cues are those which perceived to be high in reward. However a limitation to this experiment is the choice of stimuli used. Not all the stimuli classified as low calorie foods were items that you could consume immediately or by themselves (i.e. shredded wheat biscuit, plain rice). High calorie food stimuli were more representative of foods that can be eaten "at that moment" (i.e. burgers, chips, crisps and sweets). The same stimuli set were used in the study by Tapper et al. (2010) and results were consistent with this experiment. However it needs to be questioned whether the avoidance seen for the low calorie items in this experiment is confounded by the fact that these items are not ones which the individual would want to consume "right now". This is a limitation of classifying food into high calorie and low calorie groups, as it is likely that high calorie cues are those which indicate that a food is easily obtainable and can be consumed then and there. These are also features which would grab attention; the issue of whether differences in RT to high calorie and low calorie items are related to "availability" rather than perceived reward needs to be addressed in future research studies. An additional point to note is in this experiment rated pleasantness of stimuli was not a significant predictor of attentional bias.

The extent to which attentional bias is reflected in differences in body weight remains under debate (Caltri et al. 2010; Castellanos et al. 2010;Njis et al. 2010). This data showed no direct evidence that FPB was influenced by body weight. In fact, only FPB for low calorie items shown for 200ms were found to positively correlate with BMI. This finding seems somewhat paradoxical as it would be usually predicted that BMI would correlate with bias for high calorie items. However it could be argued that the relationship between BMI and FPB is evidence of a cognitive strategy used by individuals who are overweight. If an individual is aware that they are vulnerable to gain weight they may purposely direct their attention towards low calorie food items during VDP tasks. Reported heaviest ever BMI was found to predict attentional bias to both high calorie and low calorie foods on the visual dot probe task. Although the correlation co-efficient for these relationships were modest.

It can be proposed that any relationship between BMI and attentional bias is likely to be indirect and mediated by other appetite measures such as disinhibition. For example the high TFEQ_D group in this experiment were found to have higher BMI, but were also the more responsive of the two groups to food cues on the VDP task. However it is important to acknowledge that the BMI range in this sample was restricted as was the mean age of participants. The majority of participants were in their early twenties and it is likely that even though the high TFEQ_D group may exhibit a phenotype associated with weight gain, this may not be expressed as obesity until later life. It would be particularly interesting to replicate this experiment with inclusion of a follow up at 12 months; this would allow us to ascertain if the higher FPB seen in disinhibited eaters was indeed reflected in weight gain.

Experiment 2 only partially supported the initial prediction that the stimulus duration has implications for measuring FPB. This data revealed that both TFEQ-D groups displayed attentional bias for high food items when they were shown for 100ms or 2000ms. Although no significant differences were found in regards to group performance, the high TFEQ_D group showed increased bias for these items at 2000 ms where as the low TFEQ_D group had lower bias (Mean 20.95±73.41 compared to Mean : 8.206±75.48). A different pattern was established in regards to RT for low calorie items across the two durations. Both groups displayed no attentional bias for low calorie foods at 100ms. The analysis indicates that participants became quicker at responding to neutral food items compared to food items as stimuli duration increased. This trend is reflected clearly in the mean data for the High TFEQ group; at 100ms mean attentional bias was -10.99±49.03 this decreased to -33.42±76.76 at 2000ms. These findings indicate that when an individual is given an opportunity to fully attend to stimuli on an attentional task this has repercussion on their task performance. It is unclear whether the elevated response latencies seen in the high TFEQ-D group are indicative of an attempt to avoid food stimuli as this effect was only found for low calorie food items. As avoidance is often considered to reflect a cognitive coping strategy it makes little sense that this group would chose to avoid items that were not energy dense. A more sensible explanation for these findings is that low calorie items are often low in reward and thus their lower incentive salience does not allow them to "grab attention" as much as high calorie items

This experiment was designed so that the data could be analysed to ascertain if FPB reflected increased orientation to food cues or delayed disengagement. Evidence of increased orientation was only found for high calorie food items. These finding do not support those published by Tapper et al. (2009) which proposed that FPB is caused by delayed disengagement as opposed to enhanced orientation to food cues. Findings such as these illustrate the need to record eye gaze; this may produce a more reliable measure of orientation/ disengagement. Additionaly it is important to note that in order to measure disengagement/orientation the experimental design meant that food stimuli were presented less frequently across the task than neutral stimuli. It may be proposed that it is these differences in stimuli frequency which are causing the increased bias to food items (i.e. these cues are novel) however if this was the case it would be predicted that attentional bias would be seen for both high calorie and low calorie foods. This study did not find this effect.

The role that reward plays in FPB is further highlighted by the correlation all be it weak which was found between attentional bias and reward responsivity. FPB was explored by grouping participants based on their reward responsiveness and disinhibition. Low responsivity to reward was associated with higher attentional bias for high calorie food items. This mimics the findings of Experiment 1 which found that individuals whose food choices were based on reward (high hedonic eaters) were likely to have lower scores on the BIS_RR scale. This provides support for the argument that individuals who have lower signal capacity within reward circuitry are more at risk of obesity (Stice et al. 2010). Low reward responsivity would mean that individuals would need to consume higher amounts of rewarding foods to experience the equivalent degree of reward as an individual with high reward sensitivity. This may explain why low reward responsivity appears to be associated with increased FPB. However an alternative explanation for these findings is that individuals who are aware that they are highly sensitivity to reward, will develop mechanisms to reduce the impact that the presence of rewarding foods have on their behaviour. Support for this account can be seen in the fact that individuals who are most vulnerable to overeating (high disinhibition and high reward sensitivity) were those which displayed lowest attentional bias for high calorie items, whilst displaying highest avoidance of low calorie items. This suggests that low calorie items fail to grab attention in this group, but equally individuals are consciously attempting to avoid food items which are high in reward.

Throughout the study a non significant main effect of prime was found. The data indicates a trend towards individuals with high TFEQ_D scores being quicker to respond to high calorie food items after tasting the chocolate prime. The cue-reactivity literature shows that the sight or smell of a food cue is able to elicit behavioural and physiological responses even when participants are saited (for review see Herman and Polivy, 2008). Therefore the reasons underlying why the prime did not have any significant effect on behaviour in this study remains unclear. One possibility is that as participants had not fasted or been denied of chocolate prior to participation in the study it may be suggested that the prime was too small to act as a sufficient motivator. This is supported by the fact that there were no significant differences found in hunger ratings (between the prime and control prime group). The sample size used in Experiment 2 may have meant that the manipulation did not have enough power to gain statistical significance.

To summarise Experiment 2 provides evidence to suggest that attentional bias to food stimuli can be measured using the VDP paradigm. The data suggests that displaying stimuli for 100ms is a more efficient way of measuring initial allocation of attention to stimuli. It can be inferred from the data collected that all individuals (to some extent) have a tendency to respond quicker to food stimuli than neutral stimuli. These effects are only demonstrated if stimuli has high calorie content. Behavioural performance on the VDP task appears to be reflecting delayed disengagement. Individuals who score highly on trait disinhibition appear to be more responsive to food based stimuli. However the extent to which this responsivity is portrayed in behavioural performance may be dependent on reward sensitivity.

Experiment 3:
Manipulating attentional bias to food stimuli through attentional retraining.

4.3 Introduction

Experiment 2 demonstrated that individuals whose eating patterns make them vulnerable to weight gain may pay increased attention to food stimuli in their environment. However Experiment 2 provided little insight into the role that attentional bias plays in driving appetite behaviours such as food intake. To date there are no publications which have demonstrated a direct link between FPB and increased intake.

Experiment 3 is interested in establishing whether manipulating FPB could influence reported craving and subsequent calorie intake. The degree of attention that participants allocate to food cues will be manipulated using an attentional training paradigm. This procedure originated in a study which attempted to reduce the level of attention paid to threatening stimuli. Macloed, Rutherford, Campbell, Ebsworthy and Lin (2002) modified a VDP program so that the probe consistently replaced only the threat stimulus (attend condition) or a neutral stimulus (control condition). Following training participants, who had been trained to attend to the threatening images, displayed heightened attentional bias for these stimuli on a VDP task. Similarly, participants in the avoid group displayed decreased attentional bias for threatening information post training. Performance on a subsequent stressor task, revealed that the participants in the attend group were significantly more anxious than the avoid group. This study was one of the first to demonstrate that attentional training effects may not be restricted to cognitive processes but may also influence behaviour.

The attentional training paradigm has subsequently been used within the addiction literature; these studies are based on the prediction that enhancing (or decreasing) the level of attention that is allocated to a drug cue will directly influence craving and subsequent drug use. Field and Eastwood (2005) were the first to use the attentional retraining paradigm to explore craving for alcohol and subsequent alcohol intake in a group of heavy drinkers. Participants with high self reported alcohol consumption (N=40) were trained either to attend to or avoid alcohol related cues on a modified VDP task. Baseline measures of attentional bias for alcohol stimuli were recorded and contrasted to biases post training. Field and Eastwood's (2005) findings indicate that attentional training was able to successfully produce an increase in attentional bias for alcohol related stimuli (in the group trained to attend to such stimuli). This group of participants also reported significantly greater cravings for alcohol than those engaged in avoidance training. They subsequently consumed significantly more alcoholic beverages during a taste task measuring ad lib intake.

Field, Duka, Eastwood, Child, Santarcangelo and Grayton (2007) only partially replicated these findings in an extension of their work in 2007. Again heavy alcohol users (*N*=60) were trained to either avoid or attend to alcohol cues; however this study also included a control group who received no training. Following training participants completed a number of measures of cognitive bias including the stroop task, VDP (with novel stimuli), stimulus-response compatibility task and flicker induced change blindness task. This was to establish if the effects of training generalised to novel stimuli and across experimental procedures. Training was found to increase attentional bias on the VDP task to novel and familiar alcohol stimuli in the attend group, however attentional bias was only reduced for familiar alcohol stimuli in the avoid group. The effects of training not generalise to any of the other measures of cognitive bias. The control group showed no change in attentional bias. In regards to the influence of training on reported craving, craving did increase in the attend group but only in participants who were aware that they had been trained to attend to alcohol stimuli. No group differences were found in terms of alcohol consumption. This study implies that the effects of attention training are limited and do not generalise to other measure of selective attention (Field et al. 2007). Pothos et al. (2008) found only a weak relationship when comparing performance on measures of cognitive bias, this could explain why the effects of training do not seem to generalise across all measures of selective attention as in essence it is likely that they are measuring different components of attention.

Schoenmarkers et al. (2007) used attentional retraining to reduce attentional bias in heavy drinkers (*N*=106). Participants were trained to attend to either soft drink cues or received no training. Participants who were trained to attend to soft drinks displayed attentional bias these cues post training. However the effects of attentional retraining were restricted to the specific stimuli set used during training and did not generalise to other measures of attentional capture. When participant's performance was measured on a subsequent "flicker task" which contained novel items from alcohol and soft drink categories, both experimental groups displayed attentional bias for alcohol items. Retraining was not found to affect reported craving for alcohol or preference.

In 2010, Schoenmakers explored the effects of attentional retraining in a sample of alcohol dependent clients recruited from alcohol treatment centres. Participants were trained to disengage attention from alcohol related stimuli. While a control group were trained to respond to an irrelevant reaction time task. Participants, who were completed attentional retraining, showed an increased ability to disengage from alcohol related cues. However training did not reduce orientation to alcohol cues or reported craving. Although there were no group differences in the number of participants who relapsed, support for the clinical significance of this training can be drawn from the fact that participants who completed attentional retraining were discharged from the treatment centre one month earlier than those who completed the control training.

Attentional retraining has also been conducted within heavy nicotine users. Attwood (2008) found that training increased attentional bias for smoking cues in the attend group, and decrease bias in the avoid group. When participants were asked to report how much they craved a cigarette during in vivo exposure; the attend group reported higher craving however this was only significantly higher in male participants. Field, Duka, Tyler and Schoenmakers (2009) also explored the effects of attentional retraining in smokers. Although this study again found that training increased or decreased attentional bias in the predicted direction. Effects were not maintained at follow up (session retested the following day) and did not generalise to other measures of attentional capture or on a novel stimuli set.

Although the effects of attentional retraining are limited both in terms of duration and the extent to which they can be generalise to other measure and stimuli, the effect that training has on short term attentional bias appears to be fairly robust. Despite this understanding of the processes which underpin attentional retraining remains limited. Hogarth et al. (2010) proposed two arguments; the first is that attentional bias increases through learning. This account is comparable to the incentive sensitization theory which proposes that as an individual learns that a specific external cue (S+) is associated with a specific reward contingency. This association leads to more attentional processes being allocated to S+. The opposing theory is that the process of attention training allows an individual to become more effective at orienting their attention towards relevant S+. This argument makes no assumption that the individual is aware of the reward contingency associated with the symbol. Hogarth et al. (2010) tested these two predictions in a study which measures the impact on awareness of on acquiring attentional bias for smoking stimuli. Participants completed attention training task where one of three S+ were paired with a nicotine reward (puff on a cigarette). Half of the participants received prompting throughout this training so that they became explicitly aware of the symbol was paired with highest reward contingency. Attentional bias for smoking stimuli was then measured. The prompted group although able to accurate report contingency information, did not show attentional bias for the S+ following training. However the group which was not promoted show no contingency awareness but did demonstrate enhanced orientation for the S+. This study provides support for the claim that attentional retraining makes participants more efficient at orienting attention towards cues, this effect appears to be automatic. The results from this study conflict with those portrayed in Field et al. (2007) work, as it their study training only had a significant effect on participants who were aware of the training contingency.

This current experiment aims to investigate the effect of attentional training on FPB, reported craving and subsequent calorie intake of hedonic food items. This experiment used a modified VDP task to manipulate attention which is similar to the one used by Field and Eastwood (2005, 2007; 2009). Two training conditions were used in this study; participants in the first group underwent training which oriented their attention towards food stimuli, while the participants in the "avoid" group were trained to direct attention away from food stimuli. This study proposes that attentional training will produce a significant increase in attentional bias for food relevant information in the attend group, and likewise FPB will significantly decrease in the avoid group. A further prediction is that post attentional training, participants in the attend group will display highest urge to eat and reported hunger. These appetite ratings will subsequently be predicted to decrease in the avoid condition. Finally during a later taste task, it is hypothesised that participants in the attend group will display greater approach for hedonic foods, and will therefore consume significantly more food than those participants who completed the avoidance training.

4.3.1 Methods

4.3.1.1 Participants

Fifty one participants (39 Females and 12 Males) were recruited from the undergraduate population of the Swansea University. This sample size was selected as previous research that had piloted this technique in heavy alcohol users used sample sizes 40 and 60 (Field and Eastwood, 2005). Participant recruitment adhered to the selection criteria outlined in the general methodology section. Mean age of participants was 21.14 years ± 2.16) and mean BMI was 23.79 ± 5.49. There were 25 participants in the avoid group and 26 in the attend group. Participants were unaware that they would be taking part in an attentional training study and instead were recruited for a study into the effects of mood on reaction times.

4.3.1.2 Design

This study used a mixed design to assess the effect of attentional retraining on FPB. The between subjects IV of training had two levels (avoid food stimuli and attend to food stimuli). The main DV in this study was change in bias for food items baseline to post training dot probe. This was recorded in milliseconds. The amount of food (grams and calories) eaten during the taste test and preference of these foods were also used as dependant variables.

4.3.1.3 Stimulus materials and equipment

Visual Dot Probe Tasks: Baseline/ Post training

The two VDP tasks used to measure attentional bias at baseline and after attentional retraining were identical. All cues were presented for 100 ms duration. The pictorial stimuli used in the VDP task consisted of 14 colour photographs of foods related stimuli (e.g. cookies, pizza slices). Each of these pictures was paired with a neutral image taken from a single semantic category of household objects (clothes pegs, scissors). The visual characteristics of these images had been specifically chosen so that they closely resembled the main visual characteristics of the corresponding food image. Participants completed 10 practice trails during which they were asked to respond to neutral picture pairs.

Each trial commenced with a fixation cross displayed for 100 ms in the centre of the screen, the cross was followed by the presentation of a pair of pictures side by side. A probe was then presented in the position of one of the preceding pictures until participants gave a manual response to the probes position. Participants pressed one of two buttons to indicate the identity of the probe. The task consisted of 10 practice trials and presentation of 56 experimental trials, these trials were made up of 4 presentations of each of the experimental pairs (e.g. experimental stimulus shown on left followed by probe on left, experimental stimulus on left followed by probe on right, experimental stimulus shown on right followed by probe on right and experimental stimulus show on right followed by probe on left). When presented on screen, each stimulus image was 5cm high by 5cm wide. There was a distance of 6 cm between the fixation cross at the centre of each image. Participants were required to identify the location of the probe as quickly and accurately as possible. The probe position was indicated by pressing either the "f" key for left or the "j" key for the right.

Attentional Retraining Task

The attentional retraining procedure contained the same stimuli as the previously mentioned VDP tasks. During the attend training, participants completed a VDP task where the probe replaced a food related picture every time, similarly for the avoid group the probe always replaced an object. Attention training consisted of 896 trials which were split into 4 blocks of 224 trials each. Participants were advised to take a short 5 minute break in between each of the blocks to prevent fatigue or boredom. They were also provided with a glass of water during these breaks (460ml). The purpose of this training was solely to manipulate the attentional bias therefore the RT data for this task was not included in the subsequent analysis.

Questionnaire Measures

A mood questionnaire was designed to incorporate a measure of current hunger, it contained 8 VAS which rated a number of different aspects of mood (e.g. confidence, anxiety, hunger) on a scale of 0 (not at all) to 100 mm(extremely high). Participants completed the mood questionnaire at four time points during the study (on arrival, after baseline dot probe, after training, after the taste test). Report their desire to eat (measured by a modification of the desire for alcohol questionnaire, DAQ, Love et al. 1998) was also measured at the same four time points .Participants were required to rate how much seven statements matched how they were feeling right now on a scale of 0 (not at all) to 5 (extremely high). Items 1, 2, 3 and 4 on this scale were reversed scored. Items were "I have no urge to eat right now, I would not enjoy eating right now, eating would not be very satisfying right now, eating would be wonderful, I crave food right now, I could not stop myself from eating if I had some food here and my desire to eat seems overpowering". At the end of the study participants completed the DEBQ (Van Strien et at, 1986).

Disguised Taste Test

In a disguised taste task participants were presented with 70 g of Sainsbury's chocolate buttons (1549.1 kJ and 22.05 g of fat) and a 70 g portion of Maryland mini chocolate cookies (1491 kJ and 16.73 g of fat). Participants were told to taste and rate each item, and to consume as much of the items as they desired as the researcher was going to "throw away any leftovers". Foods were rated (using a visual rating scale from 0-100) on a number of attributes which included pleasantness, crunchiness and richness (Appendix *H*)

4.3.1.4 Procedure

On arrival participants were required to report their desire to eat (measured by a modification of the desire for alcohol questionnaire, DAQ, Love et al. 1998) and hunger (measured using a general mood questionnaire) at four time points during the study. Time 1(before baseline dot probe), time 2 (after baseline dot probe), time 3 (after training) and time 4 (after the taste test). Participants were then introduced to a computer based VDP task (time one, baseline measure of RT) and were informed that they would be required to attend and respond to stimuli in the form of pictures.

After the baseline dot probe participants rated their current urge to eat and mood (time 2) and began the attentional training procedure. The attend group completed a visual dot probe where the probe replaced a food related picture every time, while in the avoid group's dot probe task the probe only replaced the objects (so did not replace the food stimuli in any presentation). The purpose of this training was solely to manipulate the attentional bias therefore the RT data for this task was not included in the subsequent analysis. Participants completed a total of 896 trials which were randomised over four training blocks. After completing the training task participants again rated mood and current urge to eat (time 3). Participants then completed a final dot probe task which was used as a post training measure of food bias. This task was identical to the task used at baseline. At the end of the computer task participants were asked again to rate current mood and urge to eat.

Participants were informed that they were required to take part in an additional research study which was interested in food preference. They were seated alone at a table, in a kitchen that was away from the sight of the experimenter. On the table were two bows, one containing chocolate buttons and another containing mini cookies. Participants were told they had to make a decision about which of the two foods they preferred and they could do this by eating as much or as little of the two foods as they wished. Participants completed a visual rating scale for each food item which rated the food on a number of characteristics, e.g. how pleasant do you find this food? When finished, participants informed the experimenter and any uneaten food was removed. Participants then completed a final mood and urge to eat questionnaire (time 5). Finally participant's height (in centimetres) and weight (kg) were recorded and participants were asked to complete the DEBQ (Van Strien et al. 1986). During debrief participants were questioned regarding their awareness of the study's purpose. Once the participants had left the laboratory the researcher measured the amount of the two foods consumed. On average the laboratory session lasted for duration of 65 minutes

4.3.2 Analysis and Data handling

Kolmogorov-Smirnov and Shapiro Wilk tests showed that the variables of interest were normally distributed. FPB (baseline and post training), food preference and appetite measures were normally distributed. However calorie intake was non normally distributed.

RT's which less than 200ms were and more than 2000ms or more than 2. S.D.s above each individual participant's mean RT time was excluded as outliers. All trials with incorrect responses were excluded from the data analysis. Attentional bias scores were calculated for each participant and picture duration by subtracting the mean RT for probes replacing food pictures from the mean RT for probes replacing control pictures. Thus positive values of attentional bias scores would be viewed as reflecting of a bias favouring food pictures relative to control stimuli.

The main dependent measure of interest was attentional bias this was calculate using the above criteria. In regards to ad libitum intake, intake of mini cookies and chocolate buttons were measured individually in regards to Kcal and grams, however this was combined to produce a total measure of ad lib intake (Kcal and grams). Other dependant variables included hunger rating (0-100mm), desire to eat (0-100mm), intake (kcal) and pleasantness of foods (0-100mm).

Firstly to establish if there were any significant differences between the avoid and attend group demographics, independent t-tests were conducted. These were used to compare group's scores on DEBQ measures (restraint, external eating and emotional eating), age and BMI. Independent t-tests were also used to examine if there were any significant differences between the two groups baseline hunger. Pearson's correlations were conducted to ascertain if there was a relationship between baseline attentional bias and BMI. The probability of these was reported to two tailed significance.

Differences between the two groups baseline performance on the visual probe task were analysed using a 2 X 2 ANOVA. The between subjects factor was group (Attend and avoid) and the within subjects factor was stimuli type (response to probes replacing food items compared to responses to probes replacing neutral items). The dependent variable was reaction time (msec). An additional 2 x 2 ANOVA was used to explore change in attentional bias after training. The between subjects factor in this analysis was training group (attend vs. avoid) and the within subjects factor was attentional bias task (baseline and post training). The dependent variable was the attentional bias score.

The same set up was used to compare accuracy on the attentional task before and after training, in this analysis the dependent variable was percentage accuracy. Any significant main effects in these analyses were explored using paired t-tests, reported P values are to two tailed significance unless otherwise reported. Changes in reported hunger across training were explored using a 2 x 4 ANOVA. The between subjects factor was training group (attend vs. avoid) and the within subject factor was rating time point (time point 1, 2, 3,4). The dependent factor in this analysis was rated hunger. This analysis was repeated with the dependent variable of craving, to explore if reported desire to eat changed in response to training. Finally group differences in during the taste task were explored using independent t-tests. These were used to compare differences in rated preference of the cookies and buttons. As the measure of calorie intake was non normally distributed differences intake were explored using Mann Whitney U tests. Due to the prediction that intake may be mediated by dietary restraint; participants were classified into high and low restrained eaters by a median split on the DEBQ_R scores. Restraint was then used as a independent variable in a independent t-test to establish the effect on intake. A between subjects ANCOVA was conducted with dietary restraint as a covariate. The independent variable was training (avoid and attend) and the dependent variable was the total food consumed. Throughout the ANVOA results were checked for possible violations of sphericity and where applicable the greenhouse-geisser adjustment was applied

4.3.3 Results

4.3.3.1 Demographic Data

Table 4.5

	Attend Group *N*=26	**Avoid Group** *N*=25
Age	20.88±1.84	21.40±2.47
BMI	24.52±5.13	23.05±5.84
Gender (males: females)	6:20	6:19
Hunger baseline	43.15±28.64	42.48±25.07
DEBQ_R	2.59±0.72	2.45±0.89
DEBQ_Ex	2.80±0.78	3.00±0.86
DEBQ_Em	2.81±0.71	3.06±0.66

Mean ±SD demographic characteristics for the attend and avoid training groups

The two experimental groups were similarly matched in regards to their scores on the DEBQ measures of eating behaviour (Table 4.6). No significant differences were found between the avoid and attend groups measure of restraint [$t(49)=0.59$ $p=0.555$] external eating [$t(49)= -.89$ $p=0.380$ and emotional eating [$t(49)=-1.306$ $p=0.198$].Both groups reported similar levels of subjective hunger at baseline, and this was not found to be significantly different [$t(49)=-.089$ $p=0929$]. The standard deviations for baseline hunger indicate that within both group there were fluctuations in reported hunger levels. The two groups did not significantly differ in terms of age [$t\ (49)=-.848$ $p=0.401$] or body mass index [$t\ (49)=0.958$ $p=0.343$].

4.3.3.2 Attentional bias to food stimuli

Both groups displayed FPB at baseline

Analysis revealed that at baseline both experimental groups displayed attentional bias towards food cues [$F\ (1,49)= 13.706$ $p=0.001$]. Attentional bias was higher in the attend group (the mean reaction times being 12.40 compared to 7.47) (Table 4.7). However this differences were not found to be significant [$F\ (1, 49)=2.062$ $p=0.157$]. No significant interaction was found between Stimuli and Group at baseline [$F\ (1, 49)=0.841$ $p=0.364$]

Table 4.6.

	Attend Group	Avoid Group
RT Food Items	452.88±46.89	386.251±7.18
RT Objects	465.27±46.28	393.723±9.00
Attentional Bias	12.39±3.71	7.47±3.88

Baseline RT in ms (Mean ±SE) for food and neutral stimuli

Attentional retraining significantly influenced FPB

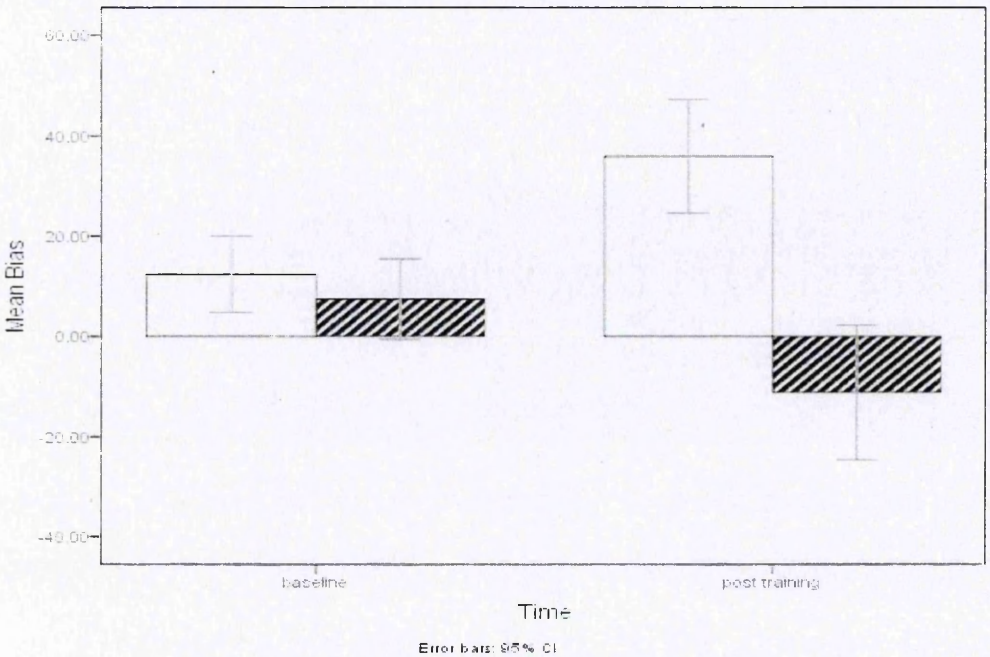
A mixed 2 X 2 ANOVA was used to compare attentional bias scores before and after training. A significant interaction was found between time and training (F (1, 49) =23.06 p <0.01) and also a significant main effect of training (F (1,49)=18.41 p <0.01). However a significant main effect of time was not found (F (1, 49) = .011 p >0.05). Independent t-test indicated that attended and avoid groups displayed significantly different FPB post training. (t (49)= -5.22 p<0.01). The attend group display a significantly higher bias to food stimuli than the avoid group (mean of 35.99 compared to -11.169 ms) (Table 4.8). Paired sample t-test indicate that for the attend group FPB significantly increased after training (t(25)=3.57 P<0.01, while the avoid group displayed a significant decrease in bias post training (t(24)=-3.32 p <0.01) (Figure 4.9)

Table 4.7:

	Attend Group	Avoid Group
RT Food Items	368.704±11.69	363.51±7.93
RT Objects	404.699±13.03	363.51±7.50
FPB	35.994±5.511	-1.169±3.87

Post Training RT and FPB in ms to food and neutral stimuli (Mean ±SD)

Figure 4.9:



Post Training RT in ms [Mean ±SE] to food and neutral stimuli

Probe detection accuracy improved in the attend group and decreased in the avoid group

Accuracy for items on the attentional bias task was compared before and after training using a mixed 2 x 2 ANOVA. The within subject factors was accuracy (baseline vs. post training) and the between subjects factor was training (attend vs. avoid). The ANOVA revealed no significant main effect of accuracy [F (1, 48) =1.726 p >0.05] and no significant main effect of training [F (1, 48) =0.013 p >0.05] There was a significant interaction found between accuracy and training group [F (1, 53) =7.53 p <0.01]. Accuracy improved overall for the avoid group (87.08% rising to 93.08%) where as the attend group become less accurate overall over the course of the training (90.69% compared to 88.58%). However mean accuracy still remained above 87% for the avoid group.

4.3.3.3 Reported craving and hunger

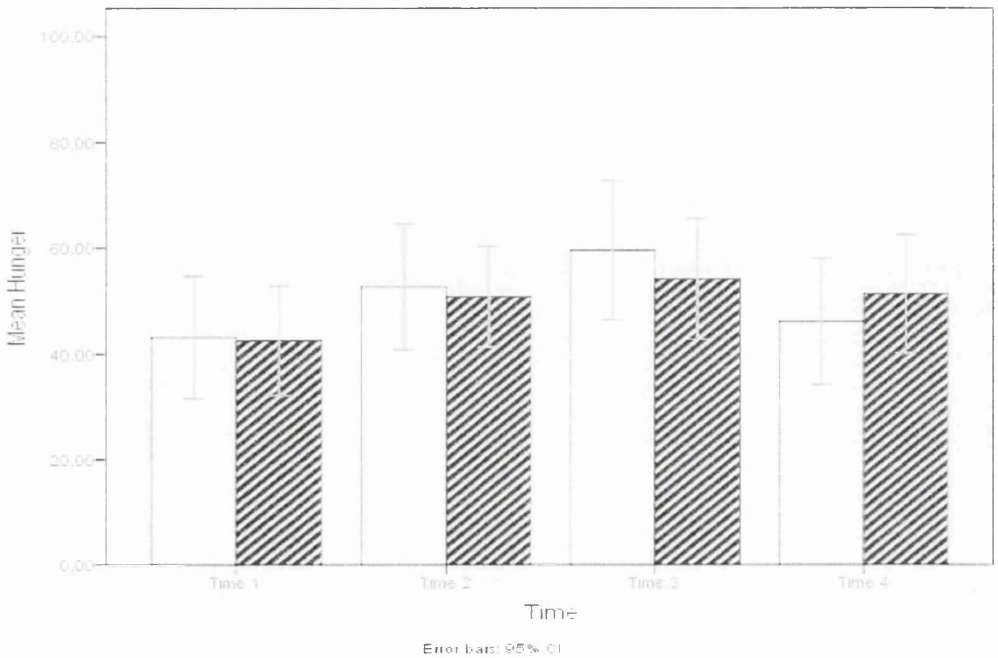
Hunger increased in both groups following training

Hunger ratings for both groups increased over the course of the computer based tasks returning to baseline levels after the taste test. At all time points the attend group reported higher hunger (Figure 4.10a) A mixed 2 X 4 ANOVA was used to compare the two groups reported hunger; the between subject factor was training (attend and avoid) and the within subjects factor being hunger (time 1, time 2. time 3, time 4). This revealed and a significant main effect of hunger [F (3, 144)=7.69 p <0.01]. However there was no significant interaction between training and hunger [F(3,144)=1.29 p P>0.05]. There was also no significant main effect of training [F (1,48)=0.41 p >0.05].

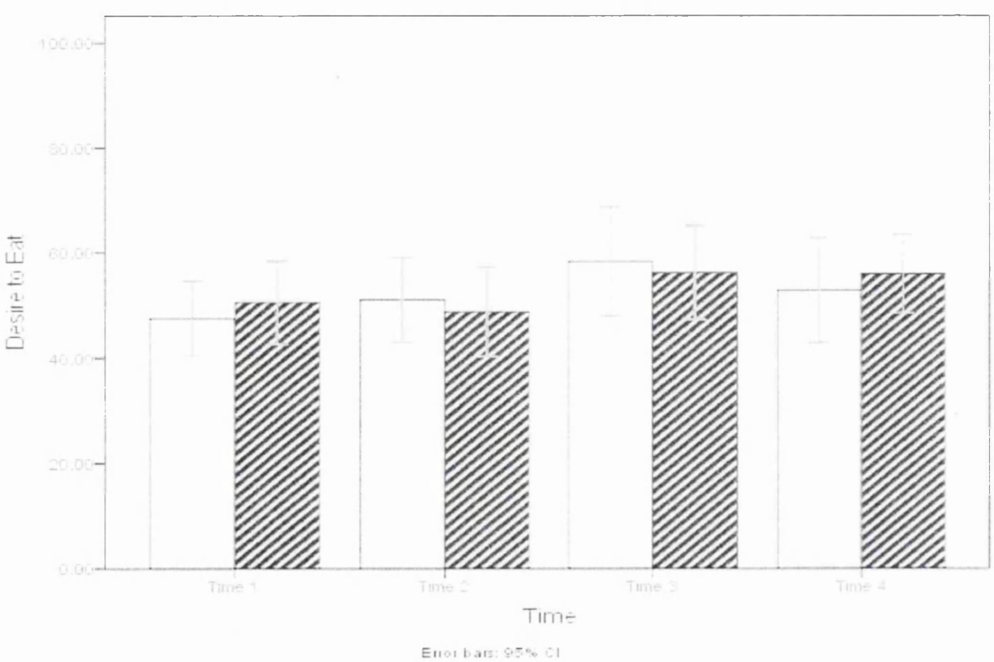
Desire to eat increased in both groups following training

At time one reported desire to eat was similar for both training groups, comparable to reported hunger craving increased over the course of the computer based tasks and returned baseline levels after the taste test (Figure 4.10 b). At all time points the attend group reported higher desire to eat. A mixed 2 X 4 ANOVA was used to compare desire to eat between the two groups, the within subject factor was training (attend and avoid) and the between subjects factor being desire to eat score (time 1, time 2. time 3, time 4). The analysis revealed a significant main effect of desire to eat[F(3,147)=5.54 p <0.01]. No significant main of training [F (1,149)=0.007 p >0.05]. There was no significant interaction between desire to eat and training [F (3,149) = 0.860 P>0.05]. Independent t-tests revealed a significant difference (for both groups) in desire to eat between from), time one and time 3 [t (50) =-3.26) p <0.01] and time two and time three [t(50)=-3.49 = p <0.01]However the two groups did not significantly differ on reported desire to eat at any of these times [p >0.05]

Figure 4.10



A) Graph showing mean (±SE) hunger for each group across the four time points



B) Graph showing mean (±SE) reported desire to eat across the four time points

4.3.3.4 Intake

No group differences in rated pleasantness of food items

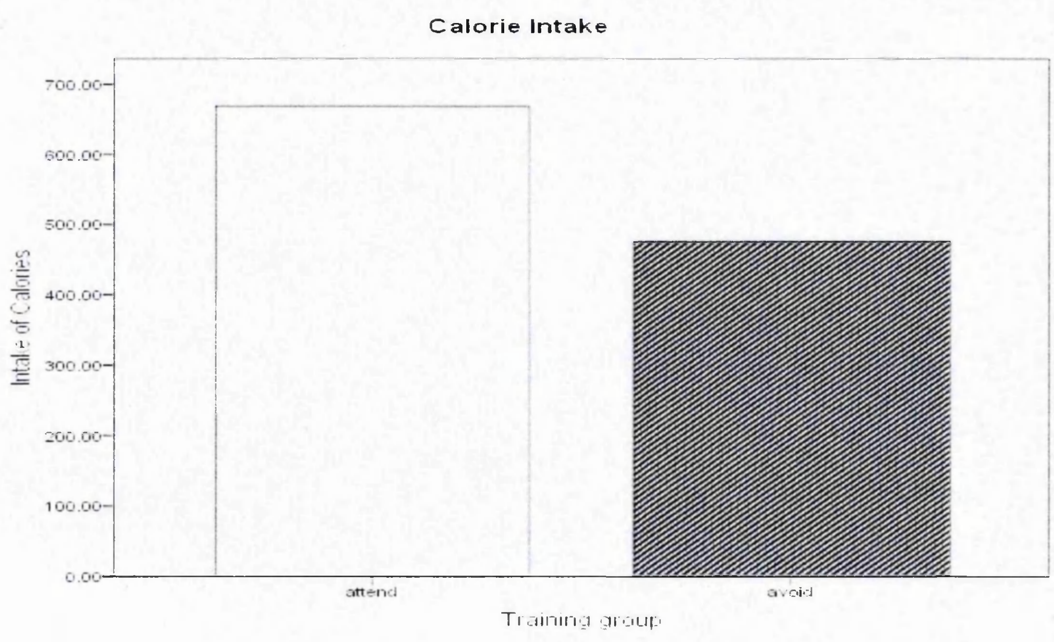
Participants rated how much they liked the cookies and chocolate buttons. In general liking for the two foods was high (>65) (Table 4.9). There were no significant differences in the groups ratings of total preference [t (49) =0.307 P=0.760] or for individual foods (Cookies, [t (49) =-.705 p =0.484; Buttons t (49) =1.127 p =0.265].

Table 4.8

	Attend Group	Avoid Group
Total Preference (max 200)	149.153±29.38	156.63± 29.36
Cookies	74.26±12.88	68.07±24.78
Chocolate Buttons	74.92±21.27	78.66±16.14

Rated pleasantness of the foods consumed during the taste task(Mean ±SE)

Figure 4.11 :



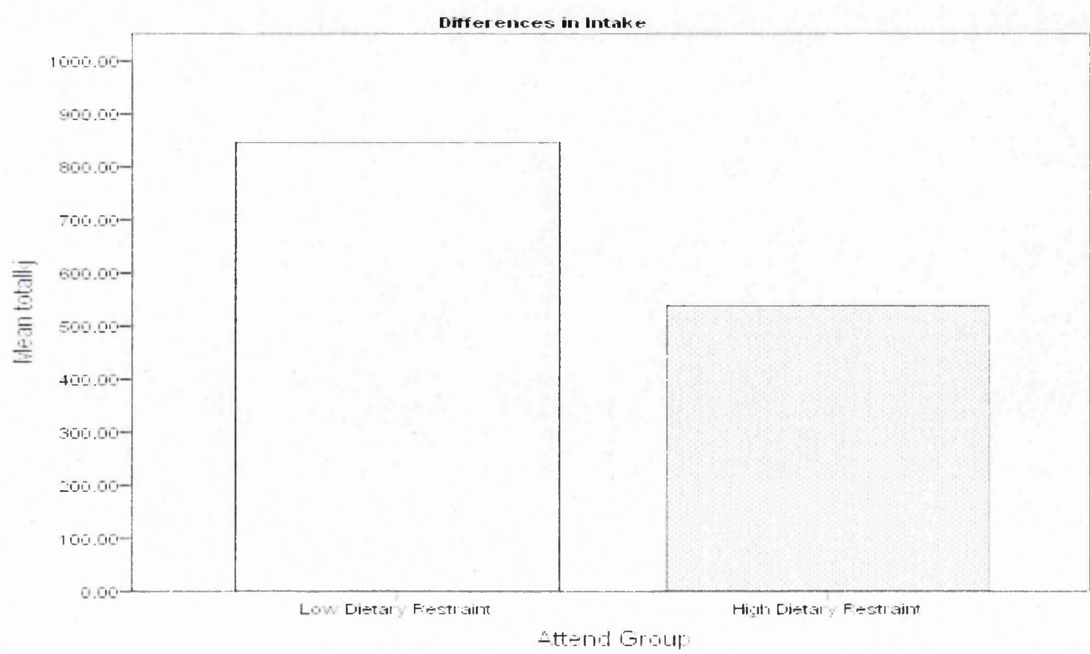
Mean [±SE] calorie intake for the two avoid and attend group

The attend group consumed more food following training than the avoid group

Participants in the attend group ate more cookies and buttons than the participants in the avoid group [37.44 g compared to 28.63 g] (Figure 4.11). The attend group consumed the most food overall [669.04 kcals compared to 476.16 kcal]. There was no relationship found between ad libitum intake and BMI [$p > 0.05$]. Independent t-test showed that the amount of food [g] consumed by the attend group was significantly higher than what was consumed by the avoid group [t (42.62) =1.85 p =0.035]. This difference was only significant to a one tailed level.

A median split was performed on the variable of dietary restraint as independent t-tests reveal that participants with low restrained eating ate significantly more during the taste test (t(30.24)= 2.173 $p < 0.05$). Therefore a between subjects ANCOVA was conducted using level of dietary restraint as a covariate, the independent variable was training (avoid and attend) and the dependant variable was total food consumed (grams). Results indicated that restraint category was a significant covariate (F (1, 48) =6.52 $p < 0.05$). There was a significant main effect of training when the covariate of dietary restraint was controlled for [F (1, 48) =4.79 p <0.05) [Figure 4.12]

Figure 4.12



A) Calorie Intake (Mean±SD) for based on dietary restraint for the attend group

B) Calorie intake (Mean±SD) based on dietary restraint for the avoid group

4.3.4 Discussion

The results from Experiment 3 indicate that training individuals to attend or avoid food stimuli on a dot probe task can successfully manipulate FPB. Both participants groups displayed attentional bias to food stimuli at baseline (this is that they responded faster to food cues than non food cues). In support of claims that the obese are likely to display heighted reactivity to food cues, baseline attentional bias was found to positively correlate with body mass index. As predicted training significantly enhanced attentional bias for food cues in the "attend" group and decreased attentional bias in the "avoid" group. This is indicated by the significant interaction found between time and group. Post training the avoid group no longer displayed FPB, in fact they were quicker at reacting to stimuli containing objects than food. This data lends further support to claims that bias for stimuli can be experimentally manipulated (Field et al 2005; 2007,2009)

This study predicted that the different training conditions would have varying impacts on rated hunger and desire to eat. Due to the proposed relationship between FPB and craving it was hypothesised that participants engaged in a training paradigm which focused their attention towards food cues, would as a direct consequence of increased attentional bias report heighted food craving. Likewise it was expected that aversion training would have a negative impact on appetite ratings, with participants in the avoid group reducing their ratings of cravings and hunger across the course of the study. However contrary to initial expectations, appetite ratings actually increased for both groups post training with no significant differences being found between the two conditions. However hunger and desire to eat ratings were higher in the attend food group across the four time points.

Although analysis revealed no significant between group differences on reported hunger and desire to eat. There were consistent within group differences in appetite ratings across the four time points. For instance, hunger and craving was rated highest at time point 3 (immediately post training), suggesting that being exposed to food cues during VDP tasks results in increased hunger and desire to eat regardless of which the cues individual's were motivated to attend to.

In regards to the impact of attentional retraining on feeding behaviour; the attend group had significantly higher ad libitum intake of calories than the avoid group. However this was only gained significance at a one-tailed level. Although this difference was small it lends support to the idea that exposure to certain stimuli (e.g. drugs, hedonic foods) may result in increased approach behaviour. Calorie intake across the two group's appears to be influence by the individual's level of dietary restraint. Analysis revealed that participants who scored low on measures of dietary restraint ate significantly more than restrained eaters. In terms of training, individuals who were low on dietary restraint were those that eat significantly more in the attend group. This finding reveal that although it is possible to experimentally manipulate individuals approach to food stimuli, it may be other factors (e.g. level of dietary restraint) which ultimately determine whether cognitive bias are actually expressed through behaviour.

In a later replication of their 2004 study, Field et al. (2007) only partially reproduced their original findings. In this replication no significant differences were found between group intakes on the taste task. Field et al. (2007) interpretation of their findings was that attentional bias could be more closely associated with subjective craving that actual drug seeking behaviour. However as this present study findings are inconsistent with this interpretation as it failed to demonstrate any significant differences between subjective cravings between the two training groups. One reason for this may be that the measure of craving used in this study was restricted as it did not measure craving for the specific food items used in the taste task, instead the scales accessed food craving and desire to eat in more generally. As Lowe et al. (2010) predicted that hedonic hunger may underpin food intake (particularly in terms of highly palatable foods) the appetite measures used in this study (Desire For Foods, and physiological hunger) may not necessary be useful predictors of food intake. It may be proposed that stronger effects may have been found if a measure of "desire to eat for hedonic pleasure" was used along with a scale specifically measuring degree of chocolate craving (e.g. ACQ- Benton, 1998). Recommendations for future research would be to replicate this paradigm using a more varied measure of ad libitum intake – preferable a buffet style task which measures intake of a range of sweet and savoury foods. This study would also benefit from including a control group which did not complete any attentional retraining. Hardman, Etchelles, Houston , Munanfo and Rodgers (2011) further developed the attentional retraining paradigm outlined in this task. They specifically examined the impact of attentional retraining on restrained eaters. In support of this study's findings, attentional retraining successfully increased bias to food cues in the attend group, and decreased for in the avoidance and control group. Again replicating this study's findings hunger increased across all three conditions. This study found no increase in intake in the attend group. However individuals who were scored high on dietary restraint did not increase their calorie intake in the subsequent taste task. This could suggest that inducing FPB is likely to promote restrained eating patterns than to be a driver of overeating.

This raises an interesting discussion point; although this study provides a degree of evidence which suggests than attentional bias to food cues is able to motivate individuals to overeat. It is also important to establish why paying more attention to food cues appears to promote self regulatory behaviours in individuals who have high dietary restraint. It could be proposed that this is not caused by attentional mechanisms per say, but rather that training primes this group of individuals to think about their diet goals, body weight. This would be supportive of the counteractive control model outlined by (Trope and Fishbach, 2000); this model proposes that when an individual who highly concerned by their weight is confronted with tempting food cues this exposure may not necessarily lead to overeating. Rather the cue may remind them of their dieting goal and which will allow them to control their food intake. However empirical evidence that food cues has this effect on weight concerned eaters remains inconsistent (Coelho, Jansen, Roefs, Nederkoorn, 2009). To summarise this study provides evidence to suggest that attentional bias for food stimuli can be manipulated experimentally. Increased FPB is associated with higher craving and hunger, and a small but significant difference was found in the amount of food that was consumed in the attend group.

4.4 Chapter Discussion

Chapter 4 demonstrated that food cues are able to command greater attention than neutral cues in the environment. Experiment 1 (Chapter 3) indicated that there are a number of eating patterns that are associated with a heightened risk of weight gain through overeating. One of these eating patterns (Disinhibition) was shown in Experiment 2 to be predictive of heightened sensitivity to food cues in the environment. The experiment demonstrated that individuals who have high trait disinhibition allocate greater attention to high calorie food stimuli on a VDP task. Measures of FPB were only significantly greater in the high TFEQ_D compared to the low TFEQ_D group for trials where the food item was high calorie. The experiment 3 explored the extent to which attentional bias can be successfully manipulated through training. Participants trained to attend to food cues on the visual dot probe task increased FPB, whereas avoidance training had the opposite effect. The data collected in this study supports claims that attentional bias is a contributing factor in overeating; as participants trained to attend to food items had higher calorie intake post training. Both Experiments (2 and 3) used the VDP task, and provided evidence to support the argument that this index of attentional bias is reflected in body weight (Caltri et al. 2010).

4.3.4.1 Summary of main findings

- Food cues command greater attentional resources than neutral items on the visual dot probe task.
- High disinhibition (TFEQ_D) is predictive of increased FPB but only for high calorie stimuli.
- There is limited evidence for the existence of FPB for low calorie food items.

- There stimuli duration has limited effects on indices of FPB. Although greater FPB was recorded in response to high calorie shown for 2000ms compared to 100ms. This was not statistically significant.
- FPB in Experiment 2 was associated with increased orientation.
- In both studies FPB was a weak predictor of BMI. In Experiment 2 it only FPB for low calorie items shown at 2000ms were found to correlate with reported BMI.
- FPB has the potential to directly influence intake behaviour. Participants who were trained attend to food items on a VDP task had higher calorie intake. However dietary restraint appears to mediate the extent to which FPB results in increased intake.
- Attentional retraining did not significantly influence craving.

Chapter 5

Exploring attentional processing of novel cues paired with food reward.

5.1 General overview of chapters aims

In Chapter 4 a number of general criticisms of using the VDP as a measure of FPB were raised. For the most part, recent work using the VDP task has been reliant on food images or words as stimuli. Although this is a logical methodology, current research does not fully address how an individual's food preferences, learning history and dieting history influence their task performance. For example it is likely that RT's measured by the VDP are influenced by how much a participant "likes" the food item shown in a picture pair. Limited previous research has attempted to factor in the effects of food preference on RT (Brignell et al. 2009). RT on the VDP are also likely to be influenced by food related emotions, prior experiences and learning history. Ambilivance could influence responses to food stimuli; participants may find images of palatable foods highly pleasant and salient however if they actively avoid consuming this type of foods this may have implications on task performance. Ambilivance could affect behaviour in a variety of ways; heightened preference may be reflected in hyper vigilance for food stimuli, delayed disengagement or avoidance.

Another general limitation of the VDP is that it measures only a specific behavioural response and cannot explore attentional processes that occur before the probe location has been identified. A way to gain insight into these earlier attentional processes is to measure electrophysiological responses to salient stimuli. (Gao et al. 2011). Chapter 5 will explore the extent to which event related potentials (ERP's) can index the degree of attention being allocated to food stimuli; a central prediction of the ERP literature is that a salient stimulus has more attentional resources allocated to its processing (Herrmann et al. 2000, 2001; Lubman et al. 2009; Namkoong et al. 2004; Warren and McDonough, 1999).

Chapter 5 sets out to extend the current FPB literature by using a paradigm which measures attentional capture of food cues but does not use food images or words as stimuli. The experiments in this chapter are based on the assumption that rewarding cues in the environment become salient through classical conditioning processes. Repeated pairing of cues with dopamine release in the nucleus accumbens increases incentive salient properties (Berridge and Robinson 1998). These experiments aim to establish the extent to which novel neutral cues can acquire increased incentive value through being paired with chocolate reward. In this chapter participants will be trained to associate neutral stimuli with varying degrees of chocolate reward using a novel cue conditioning paradigm. Experiments 4 and 5 will used the trained symbols on a attentional blink (AB) task to explore the extent to which training influences the degree of resources allocated to the cue. The final experiment in this thesis will explore the extent to which these conditioned cues can manipulate craving for food and drink items.

5.1.1 The Attentional Blink Task

The term "attentional blink" (AB) was coined to describe the decreased ability to report the content of two targets displayed in an RSVP stream. This deficit is only apparent when target two (T2) is presented 200-500ms after target one (T1). The literatures interpretation of the AB is that it reflects competition between the two target stimuli for attentional resources.

Currently only one publication has explored the effects of food targets using the AB paradigm (Peich et al. 2010). There is strong evidence from the wider AB literature that information that is consistent with current behavioural goals or "current concerns" is selectively processed. The AB effect has been explored within anxiety research, with a number of publications indicating that clinically anxious participants do not blink T2 if the target contains threatening content (Fox, Russo, Georgiou, 2005; Romens, 2011). When Fox, Russo and Georgiou (2005) compared blink performance between participants with high and low anxiety; anxiety was associated with an increased ability to report the content of threat words when displayed within the blink period. Romens et al. (2011) also found that individuals who scored highly on negative cognitive style (a trait associated with a higher risk of depressive disorders) were less likely to blink negative attribution words on the AB task. Emotional words (or Chinese ideographs, which vary in emotional valence) have also been shown to significantly reduce the AB effect in non clinical populations (Anderson 2005).

Peers and Lawrence (2009) provided evidence that individual differences may impact on AB performance. Their work explored the extent to which the report of emotional targets was affected by attentional control. Individuals with effective attentional control displayed stable target identification across trials and this was not affected by target content. However participants who were classified as having poorer attentional control displayed performance deficits. In line with the FPB literature these findings propose that efficient attentional control may allow individuals to be more effective at disregarding distracting stimuli in the environment (Peers and Lawrence, 2009). These effects are to some degree comparable to the relationship between the BIS measure and food cue responsively outlined in Experiment 1.

Emotional stimuli are considered to have special attentional status which enables them to be more quickly detected than neutral stimuli. These effects are amplified in samples which are likely to have "well-learnt,-information processing networks" (Romens et al. 2011, pg 6). This is what is being demonstrated in anxious participants' enhanced recall of for negative or phobic targets during the AB task. Learning is likely to enhance the detection of negative environmental features which resulting in the need to allocate fewer attentional resources to their processing" (Romens et al. 2011, pg 6). Romens et al. (2011) argument can be applied to overeating; thus individuals who have well established networks for the processing of food cues may be more effective at processing food cues on the AB task.

Piech et al. (2010) explored the extent to which the distracting qualities of food targets serve to diminished report of a neutral T2. In this study participants were shown a RSVP stream consisting of landscape distracters; T1 content was manipulated so that it either contained a neutral, romantic or food image. Participants were required to identify the orientation of T2 which was always a rotated landscape (clockwise or anticlockwise). Ability to recall the orientation of T2 was reduced when T1 was a food target. However this effect was only found for participants who were fasted, satiation was associated with increased detection of T2. Consistent with the FPB studies, hunger appears to increase the level of attention that is allocated to food cues during an AB task.

5.1.2 Electrophysiological correlates of attention

Studying event relate potentials (ERP) provides information about the depth of stimuli processing. The P300 (or P3) component is considered to be an ERP correlate of the processes associated with working memory and attention allocation (Polich and Kok, 1995). P300 is characterised by a large positive wave which appears approximately 300ms after stimulus presentation. Therefore P300 is traditionally measured by recording the largest positive peak of the ERP waveform occurring within the 250-400ms epoch. It is important to note however that the latency at which P300 is defined varies in terms of stimulus type and task conditions (for reviews see Polich and Kok, 1995). In regards to scalp distribution magnitude of P300 response generally increases in magnitude across the midline electrodes (frontal to parietal electrodes, Fz, Cz, Pz).

This ERP component is considered to be representative of higher order cognitions. Therefore its amplitude is considered to be directly related to selective attention and resource allocation (Dochin and Coles, 1988 as cited by Kranczioch, Debener and Engel 2003). It has been proposed that measuring amplitude of P300 allows a direct quantification of the degree of attentional resources (in terms of processing capacity) that are allocated to stimuli during attentional tasks (Bernat, Bunce and Shevrin 2001). This technique is subsequently used within the attentional literature as it allows researchers to establish a measure of cue saliency that exists independently from conscious control.

P300 has also been used an electrophysiological measure of allocation of attentional resources during the AB task. McArthur, Budd and Michie (1999) found a moderate associated between task performance and P300 amplitude. These publications have shown that P300 can be correlate of behavioural task performance with higher P300 amplitudes being found on trials where participants are successful at identify T2 content. However the majority of studies investigating P300 response on AB tasks are focused on establishing electrophysiological support for competing theories of attentional processing (e.g. Inference vs. Dual Stage Theory). An in-depth review of this literature is beyond the remit of this thesis.

In line with Johnson (1988 as cited by Lubman et al. 2008) suggestion that the amplitude of P300 is proportional to the complexity of stimuli and task difficulty Studies on addiction have shown that drug related stimuli evoke significantly greater P300 amplitudes in substance dependent populations. This paradigm typically measures P300 responses to images of drug and non drug stimuli (Lubman et al. 2007). Lubman et al. (2007) found that higher P300 magnitude was only exhibited in response to drug cues when participants were substance dependent, these effects were not found in a comparable sample of non addicted participants. The P300 response to drug cues has been replicated in alcohol dependant populations (Herrmann et al. 2000, 2001; Namkoong et al. 2004) smokers (Warren and McDonough, 1999) and opiate addicts (Lubman et al. 2009). McDonough and Warren (2001) hypothesised that P300 amplitudes may be enhanced if drug users were asked to deprive themselves of a substance prior to testing. In this study smokers were asked to deprive themselves of nicotine for a 12 hour period prior to testing. Deprivation was predicted to enhance the motivational salience of the smoking cues and thus elicit higher P300 amplitudes. In this study deprivation was not found to elicit any differences in P300 response, however the manipulation was found to evoked increased N300 responses (a negative component associated with expectancy). P300 amplitudes have also been found to positively correlate with self reports of drug craving (Franken et al. 2003, 2004; Lubman et al. 2007).

Limited work has been conducted into the relationship between P300 amplitude and the saliency of food cues. Nijs, Franken and Muris (2010) did observe a correlation between the magnitude of P300 elicited by food stimuli during a stroop task and food craving scores. Higher P300 amplitudes were evoked in response to food stimuli compared to neutral stimuli, which is consistent with the idea that food cues have special attentional properties Although P300 amplitudes were not found to differ in regards to participants body weight, Nijs et al. 2010 did find that obese participants had significantly higher evoked P200 responses to food cues (compared to neutral cues) than normal weight participants. This was interpreted as being reflective of more resources being allocated to food stimuli during early stages of attention in obese adults. Following from this study, Franken et al. (2011) has recently explored ERP correlates of taste and taste conditioning. Larger P300 responses were elicited to sweet tastes compared to neutral tastes. Participants were also trained to associate novel geometric patterns with the presentation of sweet and neutral tastes. In line with the above findings higher P300 amplitudes were found in response to the geometric pattern paired with the sweet taste. This effect was generally observed among the frontal central electrode locations and is interpreted as evidence that conditioning allows neutral symbols to acquire increased motivation relevance. Consistent with Nijs (2010), Franken (2011) found a positive association between P300 amplitude and reported craving.

A recent publication by Gao, Deng, Chen, Ludo, Hu, Jackson and Chen (2011) used the AB paradigm to explore ERP correlates of attentional bias for body words. Female participants were shown a stream of household words in which T1 was a red upright "instrument word", T2 content was a fat / thin or a neutral household word. The behavioural data from this task showed no evidence of an attentional blink effect (this appears to be caused by flawed methodology as the T2 was not presented within the 200-500ms time window where the blink usually occurs). However ERP data revealed that thin words elicited the largest P300 amplitude, followed by fat words and neutral words. Participants in this study had high body dissatisfaction scores thus the elevated P300 response to thin words was interpreted as evidence for preoccupation with body image.

P300 appears to be a useful index of attention. Measuring the peak amplitude of P300 is alternative way to gain insight into the degree of attentional resources which are being distributed to a given cue. This chapter aims to combine the AB task and ERP measures to explore if novel cues can acquire incentive properties through classical conditioning.

Experiment 4:

The relationship between motivational state and incentive salience of conditioned food cues.

5.2 Introduction to experiment 4

This experiment investigates how neutral cues acquire incentive salience and later command attention. Conditioning techniques have been used to explore how novel cues can influence attention (Hogarth et al. 2010) and intake (Cornell et al., 1985; Birch, 1989; Weingarten and Elston, 1990; Van Gucht et a. 2010). In regards to appetite research, trained symbol have been shown to instigate feeding (Birch et al. 1989) even in the absence of nutritional deficits (Weingarten & Elston, 1990; Weingarten & Watson, 1982).

For the experiments in this chapter it was decided to base training on a paradigm previously used within the flavour learning literature (Brunstrom, Downes and Higgs 2001, Brunstrom, Higgs and Mitchell 2005). In a series of experiments. Brunstrom et al. (2001, 2005) trained participants to associate a novel drink flavour with a contingency of 10 %, 50 % or 90 % chocolate reward. The training task was disguised as a computer game where participants were required select which box (out of three) in which they thought a red ball was hidden. When participants correctly identified the location of a red ball they were asked to sip one of the three test drinks. Dependent on a pre-determined reward contingency, each flavour was paired with differential rates of chocolate reinforcement (10 %, 50 % or 90 %). This conditioning procedure was able to successful manipulate flavour learning in non restrained eaters; with these participants indicating elevated preference for the symbol that was paired with the highest rate of reward (90% CS+). Restrained eaters were found to prefer the CS+ which had been associated with lowest rate of reward (10% CS+) (Brunstrom et al. 2001, 2005).

A modified version of this training task was used in Experiment 4 (Brunstrom et al. 2005). It was predicted that cues associated with reward would be preferred following training. For this experiment the CS+ were used as T2 in an AB task; it was predicted that these cues would grab attention and enhance T2 detection. However as value learning is a process during which an individual learns that a stimulus is highly predictive of a positive outcome; it can be proposed that stimuli which are predictive of any outcome may become salient during tasks where cognitive capacity is limited. This prediction is based on models of animal learning (e.g. Hall, 2003) which state that salience is directly related to outcome and not valence.

Raymond and O'Brien (2009) examined the impact of value learning on AB performance. Participants were trained to learn which face stimuli were predictive of monetary reward or losses (US) (a specific face was associated with reward or loss, 0, 20% and 80% of the time).Following training face recognition was measured using a AB task; on control trials participants were most accurate at identifying were highly predictive of an outcome (regardless of whether these stimuli predicted wins or losses). However on trials where attention was constrained attention (AB) recognition only increased for faces associated with a high probability of reward (win) whereas faces which were predictive of high loss were "blinked".

In this experiment, participants were allocated to one of two experimental groups. One group were told to consume their usual diet for the 48 hours prior to laboratory attendance (non chocolate deprived) and the other was asked to refrain from consuming any chocolate products during this period (chocolate deprivation). This manipulation was included to establish motivations impact on conditioning procedure or AB performance. It accordance with the work of McDonough and Warren (2001) it was predicted that deprivation may enhance the motivational properties of the chocolate cues. During training four CS were paired with differential rates of chocolate chip reward (reward contingency 0, 10, 50 and 90%). It was predicted that participants would display greater behavioural preference for the highest rewarded stimulus.

Equally it was proposed that participants would reduce preference for symbols that had been paired with low or no reward. Following training participants completed an AB task. This required them to report the identity of T1 (number) and T2 (CS). It was hypothesised that when the targets which had been associated with a high chocolate reinforcement (CS+ 90) would command the most attention during the AB task. Accordingly performance accuracy was predicted to be higher in trials where T2 content had been paired with 90% reward and lowest where CS+ had been paired with 10% reward or no reward (CS-) Electrophysiological data was collected for a subgroup of participants during the AB task. The ERP data from this study aimed to address whether the behavioural effects of conditioning are reflected in

ERP responses to rewarded cues. It was predicted that significantly higher P300 amplitudes will be seen in trials containing symbols associated with high reward during training. From the electrophysiological data it would also be established whether the level of chocolate deprivation had any implications on evoked brain responses.

5.2.1 Method

5.2.1.1 Participants

Sixty participants (36 female and 24 male) completed the behavioural tasks in this study. EEG was recorded for a subset of 30 individuals. Participants were randomly allocated into a chocolate deprived group or non chocolate deprived group, each of these groups contained 30 participants. Participants in the deprivation group were required to refrain from consuming any chocolate based product for the 48 hours prior to the study. Participant recruitment adhered to the selection criteria set out in the general methodology section. Mean age and BMI of participants was 21.98 years $\pm$ 4.61 and 23.36$\pm$6.52 respectively.

5.2.1.2 Design

This study used a 2 x 3 mixed design to assess the effect of motivational state on incentive value of food cues. The between subjects IV of motivational state two levels (control vs. chocolate deprived). The within subjects IV of reward contingency also contained four levels (No reward, 10%, 50%, 90% reward). The main DV of interest was target detection accuracy during the AB task. P300 response was an additional electrophysiological DV.

5.2.1.3 Stimulus Materials and Equipment

The attentional blink task was run on E-prime, participants responded to trials using a six button response box. Both symbol evaluation tasks and training paradigm were adapted from a task used by Brunstrom et al. (2005). The training and evaluation tasks designed and ran using Visual Basic and participants responded to these tasks using a mouse. For more detailed methodology refer to Chapter 2.

Novel Stimuli

The novel stimuli in this experiment are outlined in more detail in the general methodology section. A total of 6 Chinese ideograms were used as novel neutral stimuli, 3 of these were used as CS+ (symbols 1, 2 and 3). The remaining symbols were not paired with chocolate reinforcement during training (CS-)

Training Paradigm

The cue conditioning procedure used in this study is outlined in detail in the general methodology section. Participants completed 90 training trials during which they were instructed to find a red rectangle hidden inside one of three boxes. CS symbols were paired with the US (milk chocolate chip) or no reward. The ordering of each CS-US pairing was randomised across all participants. To establish appropriate CS-US contingencies, the co-occurrence of a red rectangle and a particular CS pattern was predetermined from the outset. In this way each CS + pattern was paired with a sweet 90%, 50%, or10% of the time.

Cue Evaluation Task

Both evaluation tasks used in this experiment were based on a previously published task by Brunstrom et al (2001, 2005) and are outlined in section 2.8.5. The computerised task required participants to make paired comparisons of stimuli, selecting which of the two symbols shown they most preferred. Participants made comparisons of the six novel stimuli, with every possible comparison being presented twice (left-right position). This resulted in a total of 30 randomised comparisons. Participants completed the evaluation task immediately before and after the training paradigm. This task was used as a manipulation check to ascertain that training had been successful.

Attentional Blink Task

The RSVP task is outlined in more detail in the general methodology section. The task consists of 186 trials. Each trial consists of an RSVP stream with a display sequence of 5 distracters, T1 (numeric), 3 distracters, T2 (neutral stimuli) 3 distracters. Each trial started with a 600ms fixation cross followed by the RSVP stream of distractors and targets. Each item in this stream was displayed for 100 ms.

At the end of each trial, participants were required to identify the content at T1 and T2 from multiple choice selections.

Questionnaire Measures

Participants completed the TFEQ (Stunkard and Messick, 1985) prior to their attendance in the laboratory. This screening questionnaire also collected information on habitual chocolate consumption and languages. A baseline mood questionnaire was completed over the 48 hours prior to attending the testing session (Appendix G). Finally a general mood questionnaire was completed at baseline (time 1) and after final evaluation of symbols (time 2) (Appendix G). Following training participants completed a questionnaire assessing awareness of training (Appendix J) and reward contingency along with the DEBQ.

5.2.1.4 Procedure

Written informed consent was obtained prior to the commencement of the study. Depending on experimental group, participants were asked to either maintain their habitual diet or refrain from consuming chocolate products for the 48 hours prior to testing. During this period participants were required to complete mood rating scales.

On arrival participants completed the first mood rating questionnaire. The researcher then introduced the computer task which assessed baseline evaluation of the experimental stimuli. This required participants to make paired comparisons of the stimuli selecting each time the stimuli they most preferred. On completion of this task participants tasted and rated the US (a single chocolate chip). Participants then completed the training task. Participants were instructed that they would be playing a game which required them to find red rectangles hidden in the boxes on screen. They were told that when they were instructed to eat a sweet that they needed to consume one chocolate chip.

Following training participants were asked to taste and rate the US one final time. They then completed a final stimuli evaluation task (this task was identical to the task used for baseline evaluation). Afterwards participants completed a final mood rating questionnaire. Those which were in the EEG subgroup were prepared for EEG recording; the setup of electrodes took approximately 10 minutes during which participants completed the DEBQ questionnaire. Participants who did not have EEG recorded also spent 10 minutes completing the DEBQ . Participants were introduced to the AB task by completing 30 practice trials. Participants were told that they would be viewing a rapid stream of letters, among which there would be 1 or 2 targets present. Participants were informed that targets could be numeric or in the form of Chinese symbols. The researcher explained how to identify which targets they had seen using a response box at the end of each trial. All participants completed the AB task which took on average 20 minutes (EEG was recorded for relevant participants at this time). At the end of the study participants completed a awareness measures after which they were fully debriefed.

5.2.1.5 Electroencephalographic (EEG) Recording

Voltage recordings were performed on the scalp in accordance with the 32+2 system in Fp1-2, AF3-4, F3-4-Z, F7-8, FC1-2, FC5-6, C3-4-Z, CP1-2, CP5-6, T7-8, P3-4-Z, P7-8, PO3-4, O1-2-Z, plus CMS and DRL as reference channels from a 32+2 channel elastic Electro-cap. The bandwidth was set between 0.3 and 40 Hz with a sampling rate of 16384 Hz. All electrode impedances were at or below 50 kΩ. The EEG was continuously collected during the attentional blink task and edited off-line with BESA (Version: research 5.3). After baseline correction ERP mean waves were calculated for each participant at each scalp site for each trial type. Based on visual inspection of the grand average waveform P300 was defined as the average amplitude within the 250 to 410 ms time window.

In order to reduce noise only participants with more than 10 valid trials for each condition were included in the analysis. This resulted in 28 participants data being included in the reported analysis (14 non deprived, 14 chocolate deprived). For the purpose of this thesis, statistical analysis was restricted to nine electrode positions, F3,Fz,F4,C3,Cz,C4,P3,Pz,P4. This restricted electrode set was based on previous ERP analysis of P300 during an attentional blink task (Trippe et al. 2007). Only rewarded trials were included in the analyses due to the odd ball effect. This study was our first attempt at conducting electrophysiological research and unfortunately we did not foresee that our methodological design did not control for what the literature terms the "odd ball paradigm". If a stimulus occurs infrequently during an RSVP stream or attentional task it often elicited higher P300 amplitudes

(Polich and Kok, 1995). Although the number of CS trials was matched across the AB task, the non rewarded trials measured responses to 3 symbols which had not been reinforced during training. These symbols therefore had lower overall frequency compared to symbols paired with 10%, 50% and 90% reward. Correspondingly exploratory analysis revealed that the non rewarded symbols elicited highest P300 responses. Therefore the following ERP analysis only looks at the differences in P300 responses for trained cues. When appropriate the ERP data was collapsed across frontal electrode sites (F3, F4, Fz), central sites (C3, C4, Cz) and at parietal electrode sites (P3, P4, Pz).

5.2.2 Data handling and analysis

Kolmogorov-Smirnov and Shapiro Wilks showed that some of the dependent measures in this study were non normally distributed. These variables were hunger ratings (0-100) and US preference (0-100). Therefore the appropriate non parametric analysis was conducted on these factors.

The main dependent measure was target detection accuracy during the AB task (%). This could be broken down into overall accuracy, ability to recall T1, ability to recall T2 and percentage of incorrect trials which were blinked. Other dependent variables included change in symbol preference, baseline and post training ratings of hunger (VAS 0-100), along with rated pleasantness of US (0-100). In regards to the electrophysiological data the main measure of interest was peak amplitude of P300. This was calculated as the mean peak voltage value for each trial type (10%, 50%, 90% and no reward) occurring between the epoch of 258-408ms from the time that T2 was processed. Overall target detection accuracy was calculated for each of the 4 trial types (0%,10%, 50% and 90% reward). A correct trial was defined as one where both the content of T1 and T2 was correctly identified. The total number of attentional blinks (trials where T1 was correctly identified but T2 content was not correctly identified) was calculated for each participant.

Stimulus preference scores were calculated as the difference between the number of times each CS was chosen during evaluation and conditioning. Therefore stimuli preference score could range from -10 and +10. A negative score indicated that the CS stimuli was chosen more times after conditioning.

Mann- Whitney U tests were used to examine if the two groups were matched in regards to demographic characteristics and psychometric measures of appetite (e.g. BMI, habitual chocolate consumption, restrained eating (DEBQ_R and TFEQ_R), external eating, emotional eating and age). Participants rated appetite at 8 time points in the 48 hour period before testing. Mann-Whitney U tests were conducted to compare these ratings between groups; Wilcoxon signed rank tests were used to compare the ratings across day 1 and day 2. During conditioning participants rated hunger and also desire to consume more of the US provided. Mann Whitney U tests were conducted to compare the two groups rated hunger at baseline and post training. Paired t-tests were used to ascertain if chocolate deprivation increased motivation to consume chocolate. These compared ratings of "missing chocolate", thinking about chocolate and resisting chocolate from 24 hour to 48 hour deprivation Wilcoxon signed rank tests were used to compare baseline and post training ratings of hunger. The same analysis was used to compare initial and post training ratings of the pleasantness of the US along with rated desire to consume more of the US. Again Wilcoxon signed rank tests were conducted to compare US ratings before and after training.

The number of times symbols were chosen at baseline were compared using a Friedman's ANOVA. The within subjects factor was CS stimuli (0%,10%,50% and 90% reward) . The DV was the number of times the symbol was chosen at baseline. Friedman ANOVA was run for each participant group

Preference learning was then assessed using Friedman's ANOVA . This used reward contingency of the CS as a within subjects factor (0%,10%,50% and 90% reward) The DV was change in preference. Friedman's ANOVA was run for the overall data set and for each experimental group.

Based on previous analysis of data collecting using the training task (Brunstrom 2005) this data was also analysed using weighted planned comparisons. Accordingly the contrasts weights of - 1, 0 and 1 were applied to 10, 50 and 90 contingency data. The P value obtained from this analysis was dived by 2 to obtain a P value relevant to a one-tailed hypothesis. A t-test with corrected error (see Judd et al. 1995) was then conducted for each contingency and experimental group.

Performance on the AB task was analysed based on overall accuracy (trials where T1 and T2 were correctly identified). These were examined using a mixed design 3 x 2 ANOVA. The within subjects factor was training (0, 10,50,90%) while the between subjects factor was participant group (chocolate deprived vs. non chocolate deprived). The DV was accuracy. The same 3 x 2 ANOVA set up was used to compare the effect of reward contingency on number of attentional blinks and control trials.

AB performance was also examined on the basis of target detection. Participants were allocated into high or low detection groups based on a median split of AB performance. A Mixed design ANOVA as outlined above was then conducted for the high and low detection groups.

The ERP data analysis is based on recordings from a subset of participants (*N*=28). The electrophysiological data was prepared and analysed as described in the general methodology section. The effect of reward on peak voltage of P300 was examined in correct trials using a 3(reward) x 3(sagittal site) x 3 (coronal site) x 2 (group) ANOVA. This analysis was then simplified so to a 3(reward) x (electrode site) x (group) ANOVA. The within subjects factors were reward contingency and P300 response collapsed across electrode sites (anterior, central and parietal). The between subjects factor was participant group.

For all ANOVAs Mauchly's test indicated that the assumption of sphericity was upheld for all main factors therefore a corrected F value was not reported. Main effects were explored using relevant planned contrasts.

5.2.3 Results

5.2.3.1 Demographic Data

During recruitment the two experiment groups were matched for level of restrained eating as measured by TFEQ_R and frequency of chocolate consumption. Non parametric analysis confirmed that there were no significant group difference in restrained eating (TFEQ_R) [U=405 P=0.501] or habitual chocolate consumption [U= 448.50 p =0.981]. Table 5.1 indicates that both groups had low TFEQ _R scores (<4) and were regular consumers of chocolate. Although the control group had higher mean BMI [25.00 kg/m^2 compared to 21.82 kg/m^2] this difference was not found to be significant [U=349.00 p =0.268]. The groups were also matched on the DEBQ measure of dietary restraint [U=345.5 p =0.121] and emotional eating [U=404.5 p =0.500]. There was however a marginally significant difference in the two groups external eating scores as measured by the DEBQ [U=316.50 p =0.056] with the chocolate deprived group had reporting higher scores on this measure. As this effect size was small[r= -0.25] external eating was not used as a covariate in subsequent analyses. The two groups also differed in regards to age with the non chocolate deprived group being older [mean 22.80 years compared to 21.17 years][U=269.500 p =0.029] however again the calculated effect size for this difference was small [r=-0.29] and not controlled for in subsequent analyses.

Table 5.1:

Group	Non Chocolate Deprived (N=28)	Chocolate Deprived(N=29)
*Age (years)	22.80±5.46	21.17 ±3.47
BMI (kg/m^2)	25.00 ±6.62	21.82 ±6.15
Sex (male: female)	10:17	11:18
TFEQ_R	3.53 ±2.08	3.93 ±6.15
Frequency of Chocolate Consumption	4.90 ±1.54 (daily)	4.73±1.20 (daily)
*External Eating (DEBQ)	2.19±0.87	2.87±1.41
Emotional Eating(DEBQ)	2.45±1.17	2.45±0.91
Dietary Restraint (DEBQ)	1.89±0.94	2.19±0.91

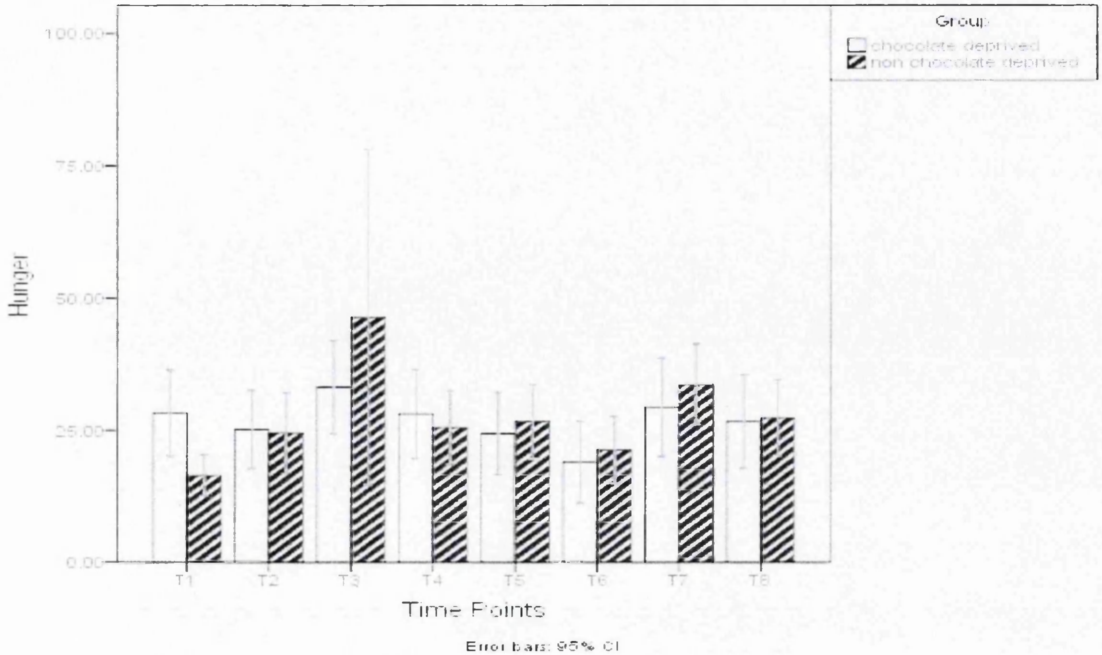
Mean ±SD demographic characteristics for the non chocolate deprived and chocolate deprived group [* indicates a significant difference between the two groups P<0.05]

5.2.3.2 Baseline ratings of appetite

No differences in rated appetite across the 48 hours prior to testing

Both groups rated their hunger [VAS 0-100] during the 48 hour period prior to their testing session. Across all participants there were 6 instances where hunger rating questionnaires were not fully completed. In these instances missing values were replaced with the series mean. Figure 5.1 shows the groups Mean±SD hunger ratings at the 8 time points;. Rated hunger was generally low across the 48 hours prior to laboratory attendance [Day one and Day two Overall Mean±SD 28.83±0.24 and 26.77 ±0.22 respectively] which is consistent with the fact that participants rated hunger after meal times. There were no group differences found in rated hunger on day one [U=-407.500 p =0.53] or day two [U=237.50 p =0.042]. There was no significant change in rated hunger from day one to day two [Z=-0.158 P p =0.874].

Figure 5.1 :



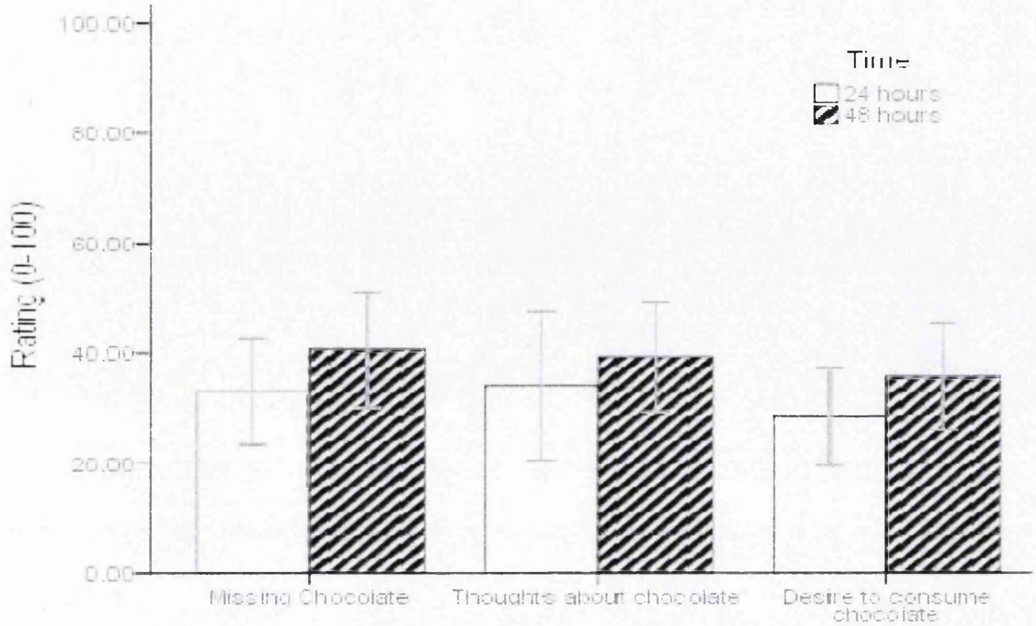
Mean (±SE) hunger for each group rated at 8 time points across the 48 hours prior to testing.

5.2.3.3 The effect of chocolate deprivation

Chocolate deprivation increased motivation to consume chocolate ,

The chocolate deprived group were asked to refrain from consuming chocolate products for 48 hours prior to testing. Participants in this group (N=29) were required to rate how much they were missing chocolate, thinking about chocolate and how difficult they were finding it to resist eating chocolate at eight time points across the deprivation period. Mean ratings were calculated for each of these measures for day one and day two of deprivation. Comparisons of mean ratings revealed a significant increase in how much participants were "missing chocolate" from day one of deprivation to day two [t (28) =--2.158 p =0.023 (one tailed)]. The calculated effect size was large [r=0.45] .This increase was also replicated for rated ability to resist eating chocolate products [t (28) =-3.017 p =0.0035 (one-tailed)]. Again the calculated effect size was large [r=0.58]. Time spent thinking about chocolate increased across the 48 hour deprivation however this difference was not significant [t (28) =-.840 p =0.206 (one-tailed)].

Figure 5.2 :.



Mean (± SD) rated desire to consume chocolate products at 24 and 48 hours prior to testing in the chocolate deprived group

5.2.3.4 Change in appetite following training

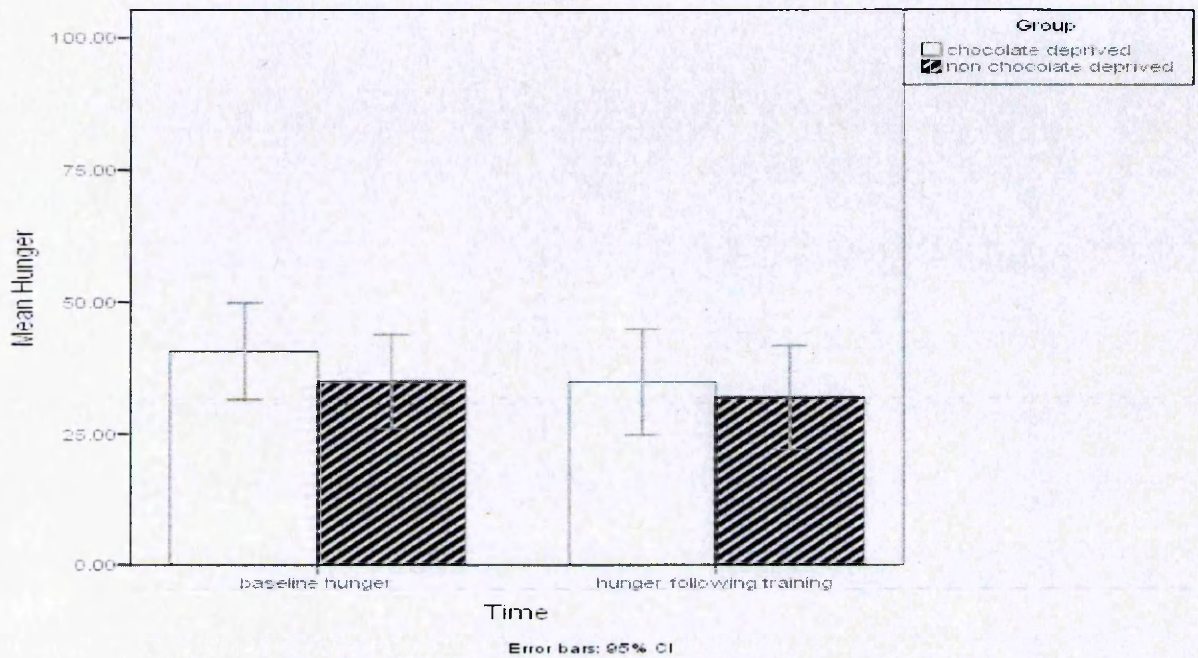
No group difference in rated hunger at baseline

Participants were required to rate their hunger when they arrived at the laboratory (time 1) and immediately after completion of training (time 2) and following the. At baseline hunger was generally low [chocolate deprived 40.72±2.41], non chocolate deprived 34.92±2.31] There were no significant group differences in reported hunger at baseline [U=404.500 p =0.501].

Rated hunger decreased following training

Following training there was a trend for both groups to rate hunger as being lower than at baseline [chocolate deprived 34.86±2.64, non chocolate deprived 31.93±2.54]. This is likely to be a consequence of consuming 60 chocolate chips (300 calories). However no significant reduction in hunger was found between time 1 and time 2 [Z=-1.35 p =0.176]. Figure 5.3 shows that following training hunger remained higher for the chocolate deprivation group. However there were no significant group differences found hunger at this time point [U=406.500 p =0.519].

Figure 5.3



Mean (±SD) rated hunger at baseline and post conditioning.

No group differences in baseline ratings of US

Baseline ratings of the US revealed that participants perceived the chocolate as being fairly pleasant (chocolate deprived M=67.21 2.18, non chocolate deprived 66.94±2.40]. No group differences were found in rated pleasantness [U=4.35 p =0.830]. Mean rated desire to consume more of the US demonstrate that participants wanted to consume more chocolate after initial tasting [chocolate deprived 63.48±2.59, non chocolate deprived 63.25 ±28.53]. No group differences were found in regards to desire to consume the US at baseline [U=4.14 p =0.594]

Following training both groups found the US less pleasant

After training both groups demonstrated a significant decreased in how pleasant they rated the US following training [Chocolate Deprived U=-2.56 p =0.010, Control U=-2.998 p =0.003]. The calculated effect sizes for both groups were large (Chocolate deprived r=0.468, non chocolate deprived r=0.547]. There were no group differences in rated pleasantness at this time point [U=438.00 p =0.859] Following training both groups decreased their rated desire to consume more of the US [Chocolate deprived U=-2.243 p =0.025, Non chocolate deprived U= -3.667 p =0.00]. Calculated effect sizes were large [Chocolate deprived r=0.409, non chocolate deprived r=0.669]. There were no group differences found in these ratings [U=0.392 p = 0.395]. To summarise these data indicate that the US was perceived as being less pleasant and less desirable following training. These effects may be caused by satiation as participants consumed around 60 chocolate chips across training this equated to approximately 300 calories.

Baseline evaluation showed equal preference for symbols

Table 5.2 displays the number of times each symbol was chosen during the baseline evaluation tasks. A Friedman ANOVA was calculated for each group comparing initial preference for the symbols which would later be associated with 0, 10%, 50% and 90% reward. There was no significant differences in the number of times any symbol was chosen for the chocolate deprived group [Chi-Square x^2=4.126 p=0.248] or the non chocolate deprived group [Chi Square x^2=3.041 p =0.385].

Table 5.2:

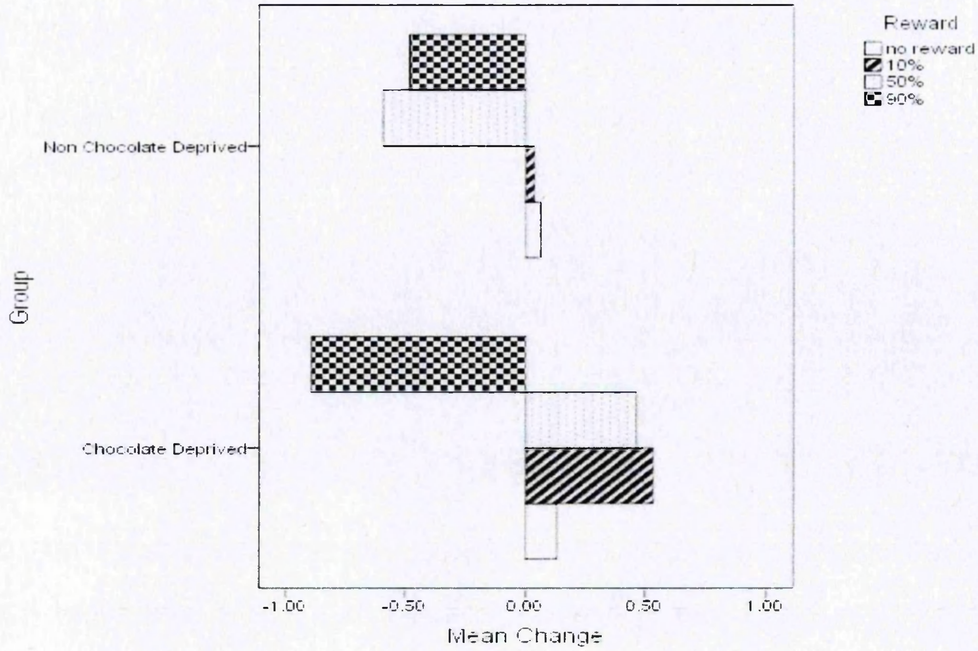
Group	0%	10%	50%	90%
Non Chocolate Deprived	4.387±1.02	5.93±3.51	5.80±3.45	5.20±3.73
Chocolate Deprived	4.51 ±1.02	5.83±3.45	5.97±3.56	4.60±3.08

Mean (±SE) number of times stimuli was chosen at baseline

Change in preference following training

Figure 5.4 demonstrates a linear trend for preference change following training. Both groups chose symbols associated with 90% reward more after training, while symbols which had not been paired with reward were disliked post training.

Figure 5.4:



Mean change in symbol preference following training for each group

Friedman ANOVA were calculated to examine the overall change scores in preference scores for each of the symbols [Chi Square x^2=5.958 p=0.114 one tailed p=0.057]. This revealed that preference change was verging on significance. Individual Friedman's ANOVAs was calculated for each experimental group. These scores provided evidence of preference learning within the chocolate deprived group [Chi-Square x^2=6.247 p=0.10 one tailed p=0.05] but not the non chocolate deprived group [Chi-square $x2$=2.216 p=0.599]. Participants in the chocolate deprived group were found to have chosen symbols which had been paired with 90% reward more frequently during the second cue preference task than symbols which had been paired with 10% (Z=-2.407 p=0.008], 50% [Z=-1.834 p=0.0335] and no reward [-1.917 p=0.027]. These tests remained significant at a one tailed level of probability after applying Bonforoni's correction.

In line with previous research using this training procedure the effects of preference learning were also analysed using weighted planned comparisons (Brunstrom, et al. 2001). This has been proposed to be a solution to limitations which exist when ANOVA designs with more than one variable and are used to perform analyses of interaction effects (Judd, McClelland and Cullhane, 1995). A weighted comparison of ratings for each subject was made, with the contrast weights

-2, -1, 1, 2 being applied respectively to the 0%, 10, 50, 90% rewarded symbols This derived a separate contrast score for each participant. The P value obtained from this analysis was dived by 2 to obtain a P value relevant to a one-tailed hypothesis.

An ANOVA with corrected error (see Judd et al. 1995) was then conducted this confirmed that there was a significant linear difference between the contrast scores [(F 1,176)-3.56 p=0.031]. This indicates that symbols paired with low reward were chosen fewer times following training, whereas symbols paired with higher reward contingencies were chosen more frequently. Training significantly influenced change scores for the chocolate deprived group [F (1, 86) =6.499 p =0.013] but did reach significance for the non chocolate deprived group [F (1, 86) =0.056 p =0.813].

Contingency Awareness

At the end of the study participants were informed which symbol they had chosen most frequently during training and were asked to state "why they preferred this symbol". Participants were then asked to complete a measure of awareness; most participants provided a response which indicated that their symbol choice was based on an aspect of the symbols visual appearance; no participant stated that their choice had been based on the fact that this was the most frequently rewarded symbol.

In total 13 participants (6 in the chocolate deprived group and 7 in the non chocolate deprived group) demonstrated a degree of awareness that the training session had involved conditioning. However no participants were able to explicitly identify which symbol had been most rewarded during training (was there any symbol which you were asked to consume a chocolate more frequently after viewing, if yes which symbol?) .This demonstrated that participants did not fully understand the purpose of the experiment and were not explicitly aware of the reward

5.2.3.5 Performance on the Attentional Blink Task

Table 5.3 displays the mean (±SE) percentage accuracy at reporting targets on the AB task. The following section will break down the analysis of the AB data in regards to overall accuracy (trials where both target content was reported), percentage of attentional blinks (trials where T1 was correctly reported but not T2) and ability to report T1 and T2 independently.

Table 5.3:

Percentage Accuracy	Trial Type	Chocolate Deprived	Non Chocolate Deprived
Overall	0%	49.69±0.034	51.64±0.041
	10 %	66.03±0.043	53.98±0.046
	50%	54.71±0.027	53.36±0.033
	90%	65.57±0.029	61.32±0.036
Blinks	0%	79.15±0.047	78.18±0.041
	10 %	63.83±0.057	65.58±0.046
	50%	66.07±0.051	66.36±0.048
	90%	68.03±0.047	68.93±0.037
T1	0%	84.55±0.038	84.75±0.049
	10 %	84.14±0.37	84.71±0.048
	50%	86.41±0.035	86.71±0.048
	90%	85.49±0.35	85.25±0.048
T2	0%	53.39±0.123	43.73±0.03
	10 %	78.89±0.122	67.33±0.049
	50%	81.59±0.109	69.93±0.038
	90%	79.92±0.123	68.43±0.045

Mean (±SE) percentage accuracy on AB task [Overall accuracy is when both T1 and T2 were correctly identified, Blinks are when T1 was correctly identified but T2 was incorrectly identified, T1 accuracy is the correct report of T1, T2 is the correct report of T2]

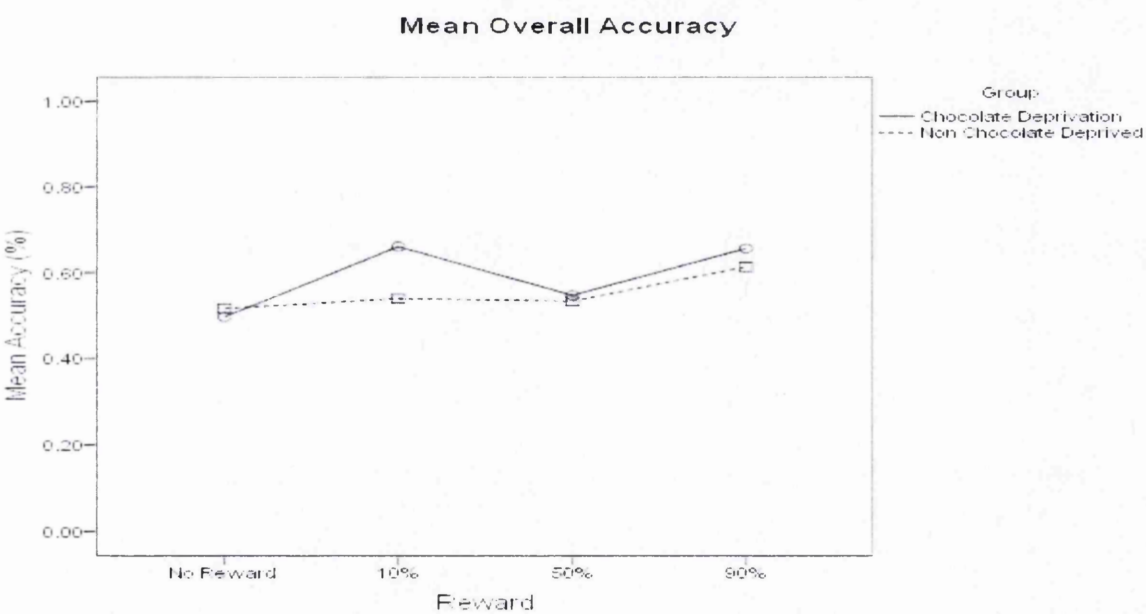
A mixed design 4 (reward) x 2 (group) ANOVA with conducted to establish if accuracy differed across the T2 conditions, but also to compare the group's performance on the task. T2 reward was the within subjects factor (0, 10, 50, 90) and the between subjects factor was group (non chocolate vs. chocolate deprived). The dependent variable was overall accuracy (percentage). The ANOVA revealed that there was no interaction between group and T2 reward [F (3,165) =1.821 p =0.145] and no significant main effect of group [F (1, 55) =1.260 p =0.267]. However a significant main effect of reward was established [F(3,165) =6.753 p =0.00].

Overall task performance was enhanced when T2 had been parried with 10% or 90% reward during training.

For overall target detection accuracy (trials where both target contents were correctly reported) a significant main effect of T2 content was found [F (3,165)

=6.753 *p* =0.00] (Figure 5.5). This indicates that participants' ability to correctly identify T1 and T2 in the RSVP stream was influenced by the training task. Accuracy was reduced on trials where T2 contained a symbol which had not been paired with reward during training (C-) [10% reward compared no reward; $F(1, 55) = 5.126$ $p = 0.28$, 90% reward compared to no reward $F(1,55)=22.349$ $p=0.00$]. Although mean accuracy was higher for trials where T2 content had been paired with the 50% reward compared to those where T2 had not been rewarded, this difference did not reach statistical significance [$F(1,55)=1.331$ $p=0.254$]. Participants accuracy was significantly impaired on trials where T2 contained a 50% rewarded symbol compared to those which contained a symbol that had been paired with 90% [$F(1, 55) = 30.906$ $p = 0.000$] or 10% reward [$t(55) = 6.196$ $p = 0.039$ (one-tailed]. There were no significant difference target detection when T2 had been paired with 10% or 90% reward [$t(56) = 0.980$ $p = 0.327$].

Figure 5.5



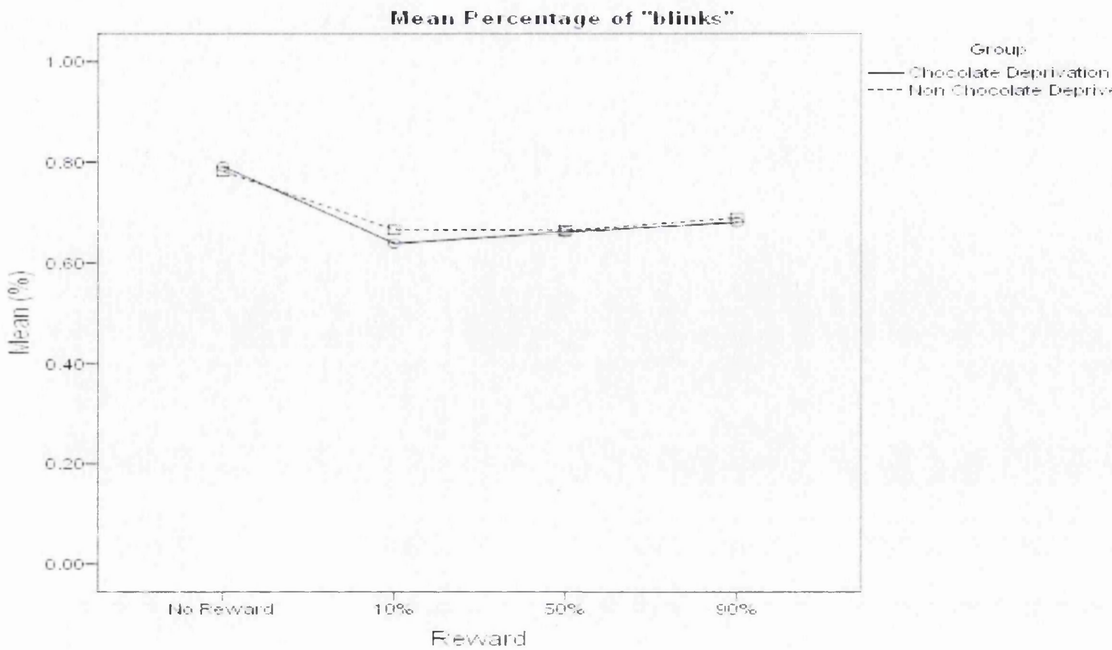
Mean percentage accuracy (%) of reporting the content of T1 and T2

Detection threshold for T2 was reduced for CS-.

A mixed design 4 (reward) x 2 (group) ANOVA with conducted to establish if attentional blinks were more likely to occur during a specific T2 condition. If the data supports the prediction that more attentional resources are allocated to symbols which are the most salient, there would be less attentional blinks seen in rewarded trials than non rewarded trials. The ANOVA also aimed to determine any group differences in performance. Again T2 reward (0, 10, 50, 90) was a within subjects factor and the between subjects factor was group (Control vs. Chocolate Deprived).The dependent variable was the percentage of incorrect trials which were attentional blinks. Analysis revealed no main effect of group [F (1, 55) =0.750 p=0.390]. However a significant main effect of T2 reward was established [F (3,165) =11.983 p =0.000].

Training significantly influenced the number blinked trials [F (3,165) =11.983 p =0.000]. Simple contrasts showed that a higher percentage of attentional blinks were found when T2 had not associated with reward. There were significantly more attentional blinks in the non rewarded trials compared to trials where T2 content had been paired with 10% reward[F(1,55)=18.36 p =0.000] 50% reward [F(1,55)=11.168 p =0.002] and 90% reward [F(1,55)=37.013 p =0.000]. The percentage of attentional blinks did not differ when T2 content had been paired with 10% or 90% reward [F (1, 55) 0.028 p =00.869] or 10 % and 50% reward (F(1,55)=2.58 p =0.114]. A significantly higher percentage of AB's was seen on trials where T2 had been paired with 50% reward compared to 90% reward [F (1, 55) =-5.44 p =0.023]. This data appears to indicate that 90% rewarded symbols were the more salient than 50% rewarded symbols during the AB task The ANOVA also demonstrated that the interaction between group and CS reward which was verging on significance [F (1,165) =2.565 p =0.0.056].

Figure 5.6



Mean percentage of incorrect trials which were classified as attentional blinks"

(T1 correctly reported, T2 incorrectly reported)

Training influenced recall of targets in control trials

The RSVP contained a number of trials where T2 appeared more than 8 stimuli after T1. These trials were used as control trials as they would not generate an attentional blink [Table 5.4]

Table 5.4 :

Trial Type	Chocolate Deprived	Non Chocolate Deprived
0%	65.48±0.034	57.71±0.050
10 %	72.90±0.044	70.19±0.57
50%	81.59±0.034	70.15±0.052
90%	67.24±0.051	70.14±0.046

Mean (±SE) percentage accuracy of reporting distant targets

Analysis showed that training significantly influenced target detection on control trials [$F(3, 165)=4.071$ $p=0.008$] . However planned comparisons revealed that the only significant differences in target detection accuracy were between non reward trials and those paired with 10% reward [$F(1, 55)=4.919$ $p=0.031$]and 50%

reward [$F(1,55)=9.758$ $p=0.003$]. No other significant differences were found in trial performance [P>0.05]

Motivational state did not affect AB performance

A mixed design ANOVA revealed that there were no significant group differences in overall target detection [$F(1, 55)=1.260$ $p=0.267$]. Equally there were no group differences in the in the number of attentional blinks [$F(1, 55)=0.750$ $p=0.390$], ability to recall T1 [$F(1, 55)=0.001$ $p=0.972$] or ability to recall T2 [$F(1, 55)$ 0.514 $p=.477$]. No interactions were found between group and target detection [P>0.05]

Training only influenced task performance when participants were efficient target detectors.

Dux and Marois (2008) identified individual differences in performance on the attentional blink task. As the raw data from this experiment showed that target detection during the AB task varied dramatically across individuals [minimum and maximum scores on trials varied from 10% to 96% accuracy]. It was important to analyse the target detection data in relation to participant performance.

Participants were allocated into either a high detection or low detection group based on a median split of mean AB performance (average percentage of correct trials across the four trial types). Twenty nine participants (14 chocolate deprived, 14 control) were allocated into the high performance group and twenty eight into the low performance group (15 chocolate deprived, 15 control). Independent t-tests confirmed target detection was significantly higher in the high detection group compared to the low detection group [$t(54)=-10.611$ $p=0.00$] [Table 5.5] .

Table 5.5:

Trial Type	Chocolate Deprived		Non Chocolate Deprived	
Detection	*High*	*Low*	*High*	*Low*
0%	53.53±0.048	44.50±0.045	62.50±0.057	40.79±0.042
10 %	77.73±0.035	53.50±0.07	65.27±0.51	42.69±0.06
50%	64.33±0.031	44.39±0.026	64.43±0.029	42.29±0.041
90%	76.30±0.027	54.07±0.035	75.75±0.026	46.89±0.041

Mean (±SE) percentage accuracy on attentional blink trials based on group performance.

Mixed design ANOVA's were conducted for the high detection and low detection groups. This was to establish whether T2 content was still a valid influence on performance when participant performance was used as a factor. In line with previous analyses. For the low detection group there was no effect of training [$F(3,78)=1.132$ $p=0.342$]. This indicates that when participants were generally poor at reporting target content, the degree to which T2 was rewarded did not influence performance. No significant interaction was found between reward and group [$F(3,78)=0.297$ $p=0.827$]. However a main effect of group was found. This demonstrated that chocolate deprived participants were significantly more accurate on the RSVP task than the non deprived group [F (1, 26] =5.098 p =0.033].

The same analysis was conducted for the high detection group. Here a main effect of training was established [F (1, 27) =7.97 p =0.00]. Simple contrasts indicate that accuracy was significantly higher for trials which T2 content contained symbols paired 90% reward compared to no reward [$F(1,27)=18.365$ $p=0.00$] . Performance was also significantly higher in 90% rewarded trials compared to 50% rewarded trials [$F(1,27)=30.44$ $p=0.00$]. In line with the original data analysis there were no difference in accuracy between 90% and 10% rewarded trials [$F(1,27)=1.654$ $p=0.209$] or 50% and non reward trials [$F(1,27)=1.838$ $p=0.186$] . Accuracy was significantly higher for trials paired with 10% reward compared to no reward [F (1, 28) =6.350 p =0.018] and 50% reward (F (1, 28) =4.355 p =0.046]. The interaction between reward and group again was verging on significance [F (1, 27) =2.369 p =0.077]. There was no main effect of group [F (1, 27) =0.177 p =0.678].

5.2.3.6. Electrophysiological correlates of cue salience

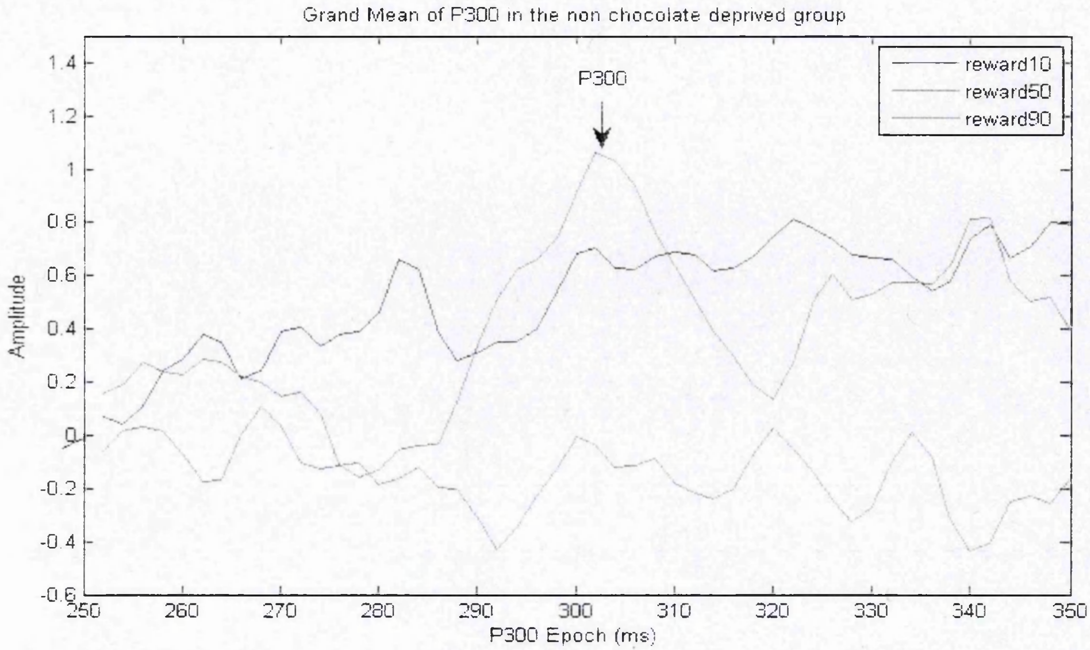
P300 was selected as this epoch reflects the degree of attentional resources allocated to processing of T2 . Figure 5.8 shows the grand average of P300 for each group (averaged across all electrodes in all correct trials). This demonstrates that P300 amplitude was highest in response to trials which contained symbols that had been paired with 90% reward. The next highest P300 response was for 10% rewarded trials and the lowest response was for 50% rewarded trials. This ERP data is consistent with behavioural findings from the AB task. There appears to be an attenuated P300 response in the chocolate deprived group compared to the non chocolate deprived group. Table 5.6 shows the mean peak amplitude of P300 averaged across frontal, central and parietal regions.

Table 5.6:

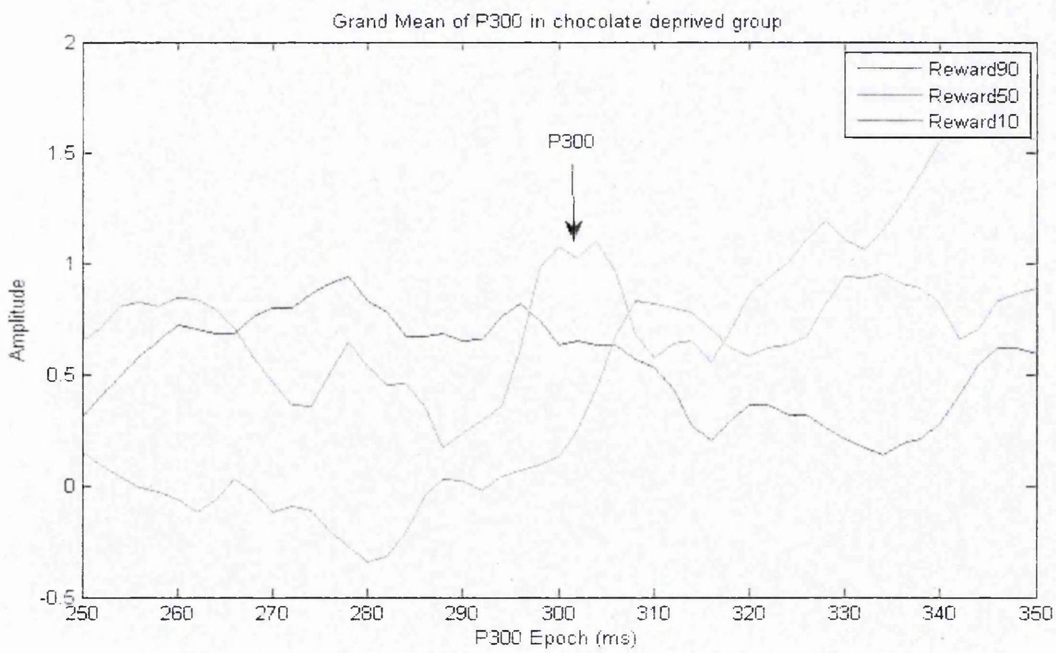
Region	Stimulus	Control Group (*N*=14)	Chocolate Deprived (*N*=14)
Frontal	10%	3.048±1.92	1.98±1.34
	50%	1.89±1.50	2.56±1.14
	90%	3.03±1.73	2.21±1.44
Central	10%	2.88±1.31	2.00±0.87
	50%	2.38±0.89	2.26±1.34
	90%	2.91±1.96	2.45±1.27
Parietal	10%	2.77±2.36	2.54±1.23
	50%	2.56±1.52	2.91±0.99
	90%	3.06±1.80	3.06±1.04

Mean Peak amplitude (±SE) of P300 collapsed across frontal (F3,Fz. F4), Central(C3,CZ,C4) and parietal electrodes (P3,Pz,P4).

Figure 5.7



(a)Grand average peak P300 amplitude (epoch 250-350) for the chocolate deprived group (collapsed across all electrodes)



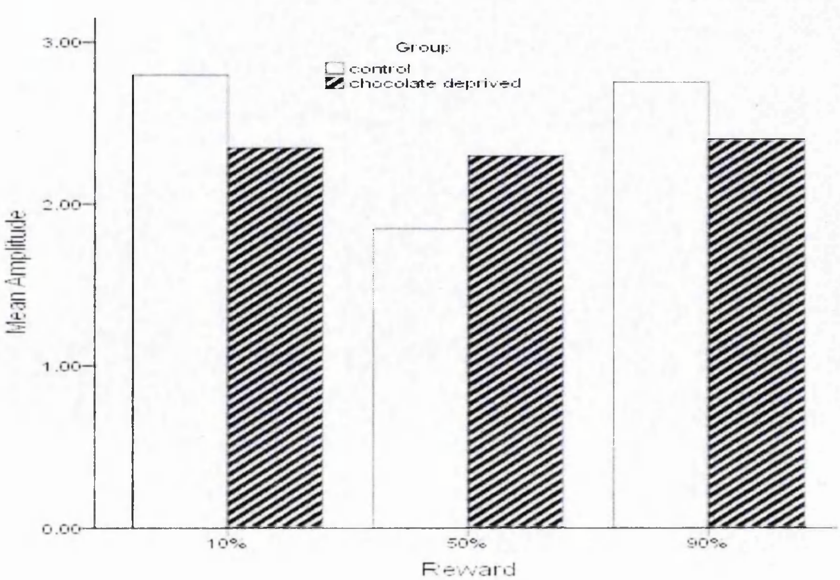
(b) Grand average peak P300 amplitude (epoch 250-350) for the non chocolate deprived group (collapsed across all electrodes)

Training only influenced P300 response in the non chocolate deprived group

Although the magnitude of P300 was highest in response to cues that had been paired with 90% and 10 % reward (Figure 5.9) no main effect of training was established [F (2, 52) =1.002 p =0.341]. However a significant interaction found between T2 reward and group [F (2, 52) =3.296 p =0.045](Figure 5.10). This interaction was explored using planned comparisons. For the control group there were no differences in peak P300 amplitude across trials which contained symbols paired with 10% and 90% [t (13) =0.113 F =0.991].However peak P300 amplitude elicited by 10% and 90% rewarded symbols was significantly higher that P300 response to CS paired with 50% reward [10% vs. 50% t(13)=3.891 p=0.002, 10% vs. 90% reward t(13)=-2.528 p =0.025]. These findings are consistent with the behavioural data from the attentional blink task and remain significant at a one tailed level after applying Bonforonni's correction.

Training did not influence P300 in the chocolate deprived group. No significant differences were found between magnitude of P300 in trials associated with 10% and 90% reward [t (13)=-0.244 p =0.811] , 10% and 50% reward [t(13)=0.327 p =0.749] or 90% and 50 reward [t(13)==0.616 p =0.548]. This appears to indicate that all rewarded CS received similar degree of visual attention in the chocolate deprived group.

Figure 5.8



Mean P300 amplitude based on reward and group

P300 response did not differ across coronal or sagittal electrode sties

There was no significant main effect of coronal electrode site [F (2, 55) =1.292 p =0.283, likewise coronal site did not significantly interact with group [F(2,55)=0.571 p =0.568]. Similarly no significant interaction was found between training and coronal site [F (4,104) =1.673 p =0.162]. There was no main effect of sagittal electrode site [F (2, 55) = 2.865 p =0.066]. Analysis revealed no significant interaction between sagittal site and group [F (2, 55) =0.915 p =0.407] or sagittal site and training [F (4,104) =0.267 p =0.899]

Training influenced P300 responses for both groups when ERP data was collapsed across anterior posterior and central electrode sites.

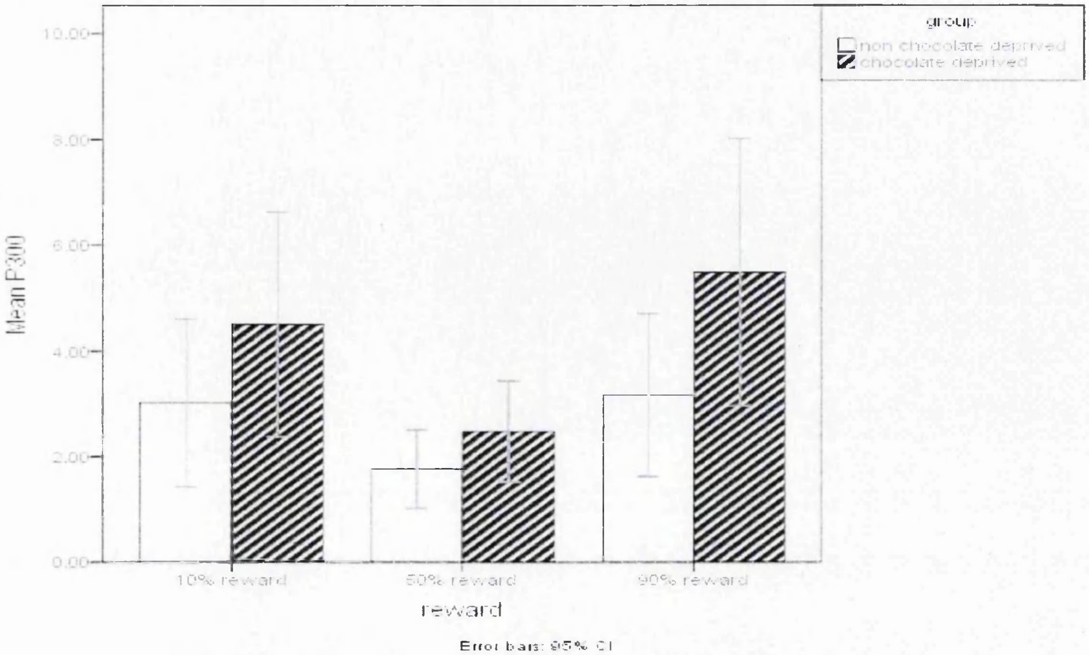
In order to improve the interpretation of the results and to reduce the number of analyses (Dien and Santuzzie, 2005) the ERP data was collapsed across anterior electrode sites (F7/8,F3/4,FP1/FP2), central sites (FC5/6,T7/T8,C3/C4) and at posterior electrode sites (P7/8,P3/4,01/02). Mean ± SD amplitude of P300 for each trial type can be seen in Table 5.7.

Table 5.7

Region	Stimulus	Control Group	Chocolate Deprived
Anterior	10%	2.37±0.85	6.82±1.45
	50%	1.62±0.39	2.14±0.30
	90%	2.46±0.85	6.63±1.36
Central	10%	3.30±0.95	5.36±1.37
	50%	1.87±0.45	3.18±0.88
	90%	3.52±0.91	5.34±1.23
Posterior	10%	3.39±0.75	2.31±0.86
	50%	1.81±0.34	2.11±39
	90%	3.52±0.73	4.50±2.05

Mean ±SE amplitude of P300 for each trial type [Anterior sites (F7/8.F3/4,FP1/FP2), central sites (FC5/6.T7/T8,C3/C4) and posterior electrode sites (P7/8.P3/4,01/02)]

Figure 5.9 :



Mean P300(±SD) response at to 10%, 50% and 90% rewarded cues

This reduced analysis revealed a significant main effect of training [*F* (2, 52) =7.759 *p* =0.001] [Figure 5.10]. Simple contrast revealed that in line with behavioural data there were no significant differences in P300 amplitude evoked for 10% and 90% rewarded trials [*t(*27) -1.059 *p* =0.299). However P300 amplitude was significantly higher for 90% rewarded trials compared to 50% rewarded trials [*t* (27) =-3.019 *p* =0.005]. Likewise P300 was higher in response to 10% rewarded T2 compared to those paired with 50% reward [*t*(27)=2.894 *p* =0.007. However in this analysis there was no significant interaction found between reward and group [*F* (2, 52) =1.117 *p* =0.335].

There were no significant differences in P300 amplitude across electrode site [*F* (2, 52) =0.184 *p* =0.398] however a significant interaction was found between group and site [*F*(2,52)=4.870 *p* =0.012]. This showed that the P300 response in anterior sites was significantly higher in the chocolate deprived group [*t* (27) =2.637 *p* =0.014]. Although P300 response remained higher in the chocolate deprived participants no other significant group differences were found [central electrodes *t* (27) =1.530 *p* =0.138, posterior electrodes *t* (26)=0.017 *p* =0.986]. Within in group comparisons between electrode sites revealed no differences between P300 response in the non chocolate deprived group [p >0.05]. In the chocolate deprived group P300 response was significantly at anterior electrodes than posterior electrodes [$t(13)=3.328$ p =0.005]. There was no difference in P300 response at any other site [p >0.05]. There was no interaction between site and reward [$F(4,104)=0.897$ p =0.469]. There were no significant group differences in P300 response [$F(1,26)=3.137$ p =0.088]

5.2.4 Discussion

These results indicate that cue preference can be successfully manipulated through classical conditioning. The procedure used in this study was to pair the novel cue (CS) with different contingencies of chocolate reinforcement. Participants generally changed their preference for symbols in a linear fashion; increasing preference for symbols which had been paired with 90% reward and decreasing preference for symbols paired with 10% and no reward. Whereas reported preference for symbols paired with 50% reward remained fairly stable. This finding also replicates the results of the paper from which we adapted our training procedure (Brunstrom et al. 2001, 2005). However it is worth noting that the paper by Brunstrom et al (2005) acknowledged that the preference change demonstrated in their studies was highly reliant on contingency awareness; with the largest changes in preference were found in participants who were explicitly aware of conditioning (Brunstrom et al. 2001, 2005). The majority of participants in this study reported that they were unaware of the experimental demands. Assessment of awareness indicated that participants had limited insight in regards to why they had chosen their "liked" symbol more frequently following training. As participants were unable to articulate that they liked a symbol because it had been paired with a high reinforcement, it seems unlikely that the change in cue preference demonstrated in this experiment was generated by explicit awareness of training. Although this contrasts with previously published research (Brunstrom et al 2005) it does parallel reviews which propose that value learning in addiction is an automatic and implicit process (Hogarth et al. 2010). The effects of training may be amplified if the cue conditioning procedure was able to generate explicit awareness.

Results of this experiment provide strong behavioural evidence that cues which have acquired incentive salience are allocated greater attentional resources (during the initial stages of attentional capture). Both participant groups were found to be more accurate at reporting the content of targets which had been reinforced during training. Interpreting these differences as being a consequence of familiarity does not appear to be valid, as accuracy was also dependent on the contingency of reinforcement. Both participant groups were significantly more accurate at reporting target content when it had been paired with the highest level of reinforcement (CS+ 90%). Correspondingly the number of times T2 was blinked was reduced when the target had been paired with 90% reward. On the premise of the attentional blink literature these would be interpreted as evidence that cues paired with 90% reward had gained "special attentional status" which allowed them to be more readily detected in during the AB task than neutral stimuli (Romens et al. 2011).

And interesting and unexpected finding was that participants were also less likely to blink targets if they had been paired with the lowest chocolate reinforcement during conditioning. In the context of value learning recognition is often found to be enhanced for any stimuli which are strongly predictive of an outcome (regardless of valence of the consequence) (Raymond and O'Brien, 2009). This may explain why performance was enhanced (to around 60% accuracy) for trials where T2 had been paired with both 10% and 90% reward. Accuracy for trials which contained 50% rewarded symbols and non rewarded symbols remained similar to chance (<50%). From an evolutionary perspective it appears rational that the attention system would allocate resources to cues that are predictive of a high and low reward. Concerns about bodyweight and health dominate the current food environment; therefore it could be proposed that individuals (regardless of their reported dietary restraint status) may be motivated to attend to information which signals a lower value of chocolate reward. However the limited contingency awareness expressed by participants restricts the extent to which it can be speculated that explicit cognitions such as these are influencing attention allocation on the AB task. Additionally participants did not generally report increased preference for the 10% rewarded cue during the cue evaluation task.

An alternative interpretation for the enhanced report of C+ paired with 10% reward is that this is caused by devaluation. Participants consumed around 300 calories during training, additionally the chocolate used as the US had a rich taste (chocolate chips used for baking). It is possible that training made participants feel nauseas. From this perspective CS+ paired with 10% and 90% rewarded could be motivational targets. In this sense the increased "preference" of the 90% rewarded symbol during training may not directly represent increased liking but rather increased saliency.

Regardless of the underlying reasons why the CS cues acquire incentive salience, the electrophysiological data does support the notion that cues associated with both 10% and 90% developed increased incentive value. This is reflected by significantly higher peak amplitude of P300 amplitudes on trials where T2 had been paired with high and low reward contingencies. However in the initial analyses these ERP effects were only demonstrated for the participants who had not deprived themselves of chocolate for the 48 hour period prior to testing. This finding appears to indicate that reward contingency was only a relevant ERP correlate for the participants who were not deprived of chocolate. Somewhat contradictory to this interpretation is the finding that the non chocolate deprived group were found to display the smallest changes in cue preference following training (note: no main effect of group was found during analysis). Although the chocolate deprived group had the larger changes in cue preference scores following training, the ERP data indicates that reinforced targets were equally salient within this group. Correspondingly no significant differences in P300 amplitude were found in data collected from the chocolate deprived group. Interpretation of this finding may be that even though participants were generally able to distinguish between which symbols they preferred on a behavioural level on an electrophysiological level these cues elicited similar levels of saliency.

When the ERP data was collapsed across the anterior, central and posterior electrode sites a mean effect of reward was established for both groups. Luck et al (2009) proposes that the most reliable analyses of ERP data is obtained when data is collapsed across electrode sites as this limits the probability of type I and type II errors. Using this approach P300 response was found to directly correspond to behavioural data. No significant differences were found in P300 response to 10% and 90% targets. ERP research has shown that P300 is sensitive reward irrespective of whether valence is predictive of a negative or positive outcome. Briggs and Martin (2009) found that P300 responses were enhanced for negative and positive pictures compared to neutral information shown during an affective picture processing task. Briggs and Martin's (2009) work was based the model of motivated attention and affective states which states that both pleasant and unpleasant stimuli are salient to the attentional system (Lang et al. 1997). P300 response in Experiment 4 was significantly higher when targets contained 10% and 90% rewarded symbols compared to when these symbols had been paired with a 50% reward or no reward during conditioning. However analysis of this restricted data set showed no evidence of a direct interaction between reward and group but did establish a significant interaction between caudality and group. The chocolate deprived group had increased P300 response in anterior sites; the anterior cingulated cortex has been related to mediation of goal direction behaviour and processing of drug cues in humans (Garavan and Hester, 2007).

Finally corresponding to previous research by Dux and Marois (2008) the extent to which cue reinforcement influenced target detection appears dependent on how proficient an individual is on the AB task. When behavioural performance was categorised into high and low target detectors, only individuals who were proficient target detectors were found to have heightened accuracy for rewarded targets. Dux and Marois (2008) interpreted these findings as evidence that high target detectors are better at ignoring distractor items in their environment. The EEG sample was not large enough to establish if training only influenced ERP response in individuals who were efficient target detectors.

Key Findings

1) The incentive value of novel cues can be manipulated through training
2) Cues associated with reward (CS+) grab attention on a AB task.
3) CS+ paired with 10% and 90% reward appear to have equal incentive value
4) Using this approach to measure how cues capture attention may reduce the impact of confounding factors such as ambilivance and learning history.

Experiment 5:

The relationship between motivational state and incentive salience of conditioned food cues on the modified attentional blink performance

5.3. Introduction to experiment 5

Experiment 4 explored how attention is allocated to conditioned cues using an AB paradigm. This experiment found that participants were less likely to blink the content of T2 if it had been rewarded during training. A modification of the AB paradigm can be used to explore if the content of T1 can increase the number of attentional blinks. Few studies have explored how the salience of T1 affects task performance (Chatton, Sours, Boettiger, 2010; Oliver, Spalek, Lawahara and Di Lollo, 2009); these have shown that proposes when T1 has high incentive value less attentional resources are allocated to the processing of T2.

Piech et al. (2010) used a similar paradigm to examine the extent to which the distracting qualities of food stimuli (T1) influenced the ability to report T2 content. The data from this study indicated that when saited participants were more accurate at reporting the content of T2 when T1 was a food item. This corresponds to the hyper vigilance hypothesis proposed by Chatton et al. (2010). However when fasted participants completed the AB task the opposite effect was found. Participant's ability to recall the T2 content was significantly reduced when T1 contained a food target. This appears to indicate that when hungry food cues grab attention and reduce the level of attentional resources allocated to the processing of T2. These effects mirrors electrophysiological findings which indicate that P300 response to food cues are heightened during fasting (Hoffman and Polich et al. 1998; Polich and Kok, 1995)

Here regular chocolate consumers who have low dietary restraint (as measured by the TFEQ_R) will be allocated into one of two experimental groups (non chocolate deprived or chocolate deprived). Experiment 5 will use the cue conditioning paradigm outlined in the Experiment 4 . Following training participants will completed a modified AB task; in this task T1 will be a Chinese symbol (US associated with either no reward, 10%, 50% or 90% reward during training) and T2 will contain a numerical symbol. It is predicted that if the content of T1 is salient

(CS+) increased resources will be allocated to its processing. Paying prolonged attention to T1 will reduce participant's ability to report the content of T2.

Electrophysiological data will again be collected for a subgroup of participants during the AB task. It is anticipated that as in Experiment 4 the behavioural effects of cue conditioning maybe illustrated in ERP response.

5.3.1 Methods

5.3.1.1 Participants

Thirty four participants (28 female and 6 male) completed the behavioural tasks in this study with EEG being recorded for a subset of 20 individuals. Participants were randomly allocated into a chocolate deprived or non chocolate deprived group. The non chocolate deprived group contained 18 participants and the chocolate deprived group contained 17 participants. One participant's data was excluded from the chocolate deprived group as they failed to consume the US during training. As with Experiment 4 participants in the deprivation group were required to refrain from consuming any chocolate based product for the 48 hours prior to the study. Participant recruitment adhered to the selection criteria set out in the general methodology section. Participants mean age was 20.63± 2.41 years and mean BMI was 22.54± 5.01.

5.3.1.2 Design

This study used a 2 x 3 mixed design to assess the effect of motivational state on incentive value of food cues. The between subjects IV of motivational state and had two levels (control vs. chocolate deprived). An additional within subjects IV of reward contingency contained four levels (No reward, 10%, 50%, 90% reward). This study had a number of DVs; however the main DV of interest was overall target detection accuracy during the AB task. P300 response was an additional electrophysiological DV

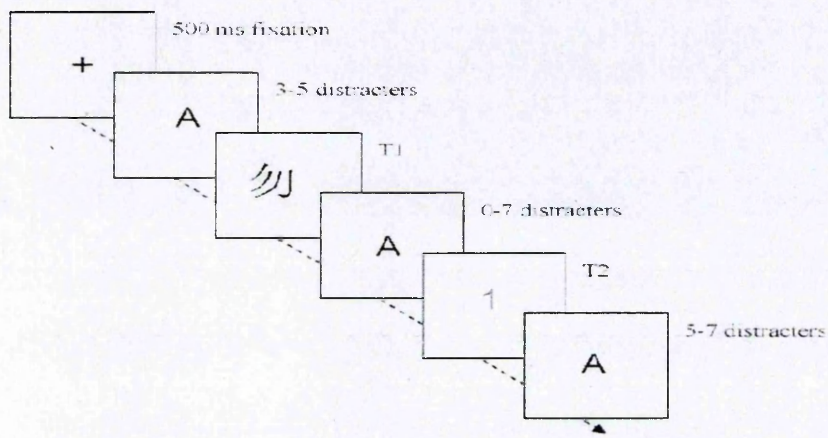
5.3.1.3 Stimulus Materials and Equipment

For details on novel stimuli, training paradigm, questionnaire measures and the evaluation task refer to previous experiment (Experiment 4)

Attentional Blink Task.

The only difference between the AB task for this experiment and that used in experiment 4 is that for this task T1 contained the CS while T2 content was numerical.

Figure 5.10



Schematic diagram of target presentation during the AB task in Experiment 5

5.3.1.4 Procedure

The procedure was identical to that outlined in Experiment 4

5.3.1.5 Electroencephalographic (EEG) Recording

The set up of electroencephalographic recording is identical to Experiment 4.

5.3.2 Data handling and Analysis

Kolmogorov-Smirnov and Shapiro Wilks showed that some of the dependent measures in this study were non normally distributed. These variables were hunger ratings (0-100) and US preference (0-100). Therefore the appropriate non parametric analysis was conducted on these factors. The main dependent measures of interest are identical to those outlined in Experiment 4. Accuracy scores (Overall target detection accuracy, number of blinks, T1 and T2 accuracy) and stimuli preference scores were calculated in the same way as Experiment 4. The statistical analysis was identical to that outlined in section 5.2.3.5

5.3.3 Results

5.3.3.1 Demographic Data

During recruitment the two experiment groups were matched in regards to level of restrained eating as measured by TFEQ_R and frequency of chocolate consumption [Table 5.8] . Non parametric analysis confirmed that there were no significant group difference in regards to restrained eating (TFEQ) [U=-0.915 p =0.384] and habitual chocolate consumption [U= -1.79 p =0.858]. Both groups had low TFEQ _R scores (<5) and reported habitually consuming chocolate at least on a daily basis. Although the chocolate deprived group had higher mean BMI (22.79 kg/m^2 compared to 21.73 kg/m^2) this difference was not significant [U=-0.253 p =0.817]. The groups were also matched on the DEBQ measure of dietary restraint [U=-1.533 p =0.125] and emotional eating [U=-1.719 p =0.086]. There was no significant difference in the two groups external eating scores as measured by the DEBQ [U=-0.398 p =0.691].

Table 5.8:

Group	**Non Chocolate Deprived (*N*=18)**	**Chocolate Deprived (*N*=16)**
Age (years)	20.944±0.67	20.18±0.44
TFEQ_R	3.94±0.45	4.69±0.56
Chocolate Consumption	5.28±0.22	5.5±0.68
BMI (kg/m^2)	21.73±1.53	22.79±1.09
Sex (male: female)	2:16	4:12
Restraint (DEBQ)	1.77±0.15	1.42±0.11
Emotional Eating(DEBQ)	2.19±0.22	1.85±0.46
External Eating (DEBQ)	2.69±0.15	2.61±0.16

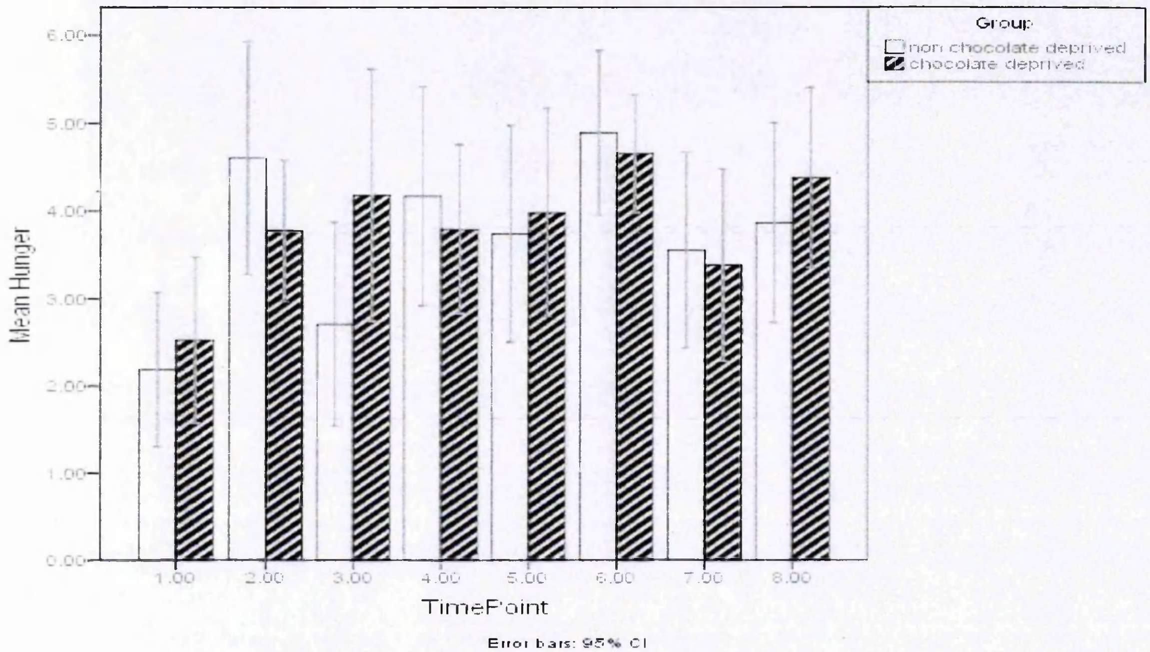
Mean (± SD) of demographic characteristics for each group

5.3.3.2 Baseline ratings of appetite

No differences in rated appetite across the 48 hours prior to testing

Both groups rated their hunger [VAS 0-100mm] during the 48 hour period prior to attending their testing session (Figure 5.12). Across all participants there were 10 instances where hunger rating questionnaires were not completed fully. Missing values were replaced with the series mean. Examination of the mean data shows points that although hunger was generally low across all time points. There were no significant group differences in reported hunger at day one [$t(32)=0.064$ p =949] or at day 2 [t(32=0.451 p =0.655] For both groups rated hunger was higher on day 1 than on day 2 . However ratings across this period did not differ significantly [$t(33)$=--1.862 p =0.072].

Figure 5.11



Mean (± SD) rated hunger for each group at 8 time points across the 48 hours prior to testing

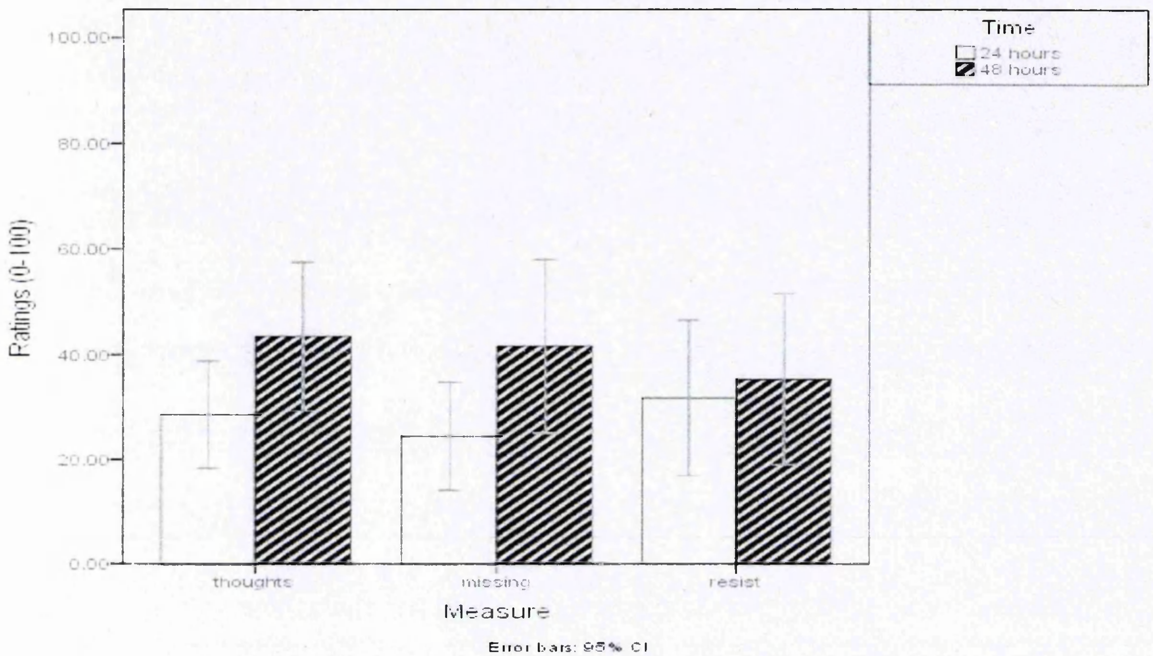
5.3.3.3 The effect of chocolate deprivation

Chocolate deprivation increased motivation to consume chocolate

The chocolate deprived group were asked to refrain from consuming chocolate products for 48 hour period preceding testing. Participants in this group were required to rate how much they were missing chocolate, thinking about chocolate and their difficulty resisting eating chocolate at eight time points across the 48 hour deprivation. Mean ratings [Figure 5.13] were calculated for each of these measures at 24 hour and 48 hours. Paired samples t-test revealed that there was a significant increase in participants ratings of "missing chocolate" across the 48 hours deprivation [t (15) -3.085 p =0.010]. A significant increase was found in ratings of time spent thinking about consuming chocolate [t (15) =--3.085 p =0.012].

There was no significant increase in difficulty in resisting consuming chocolate [t $(15)=-.330$ $p=0.74$]

Figure 5.12:.



Mean (± SD) rated desire to consume chocolate products at 24 and 48 hours prior to testing in the chocolate deprived group

5.3.3.4 Change in appetite following training

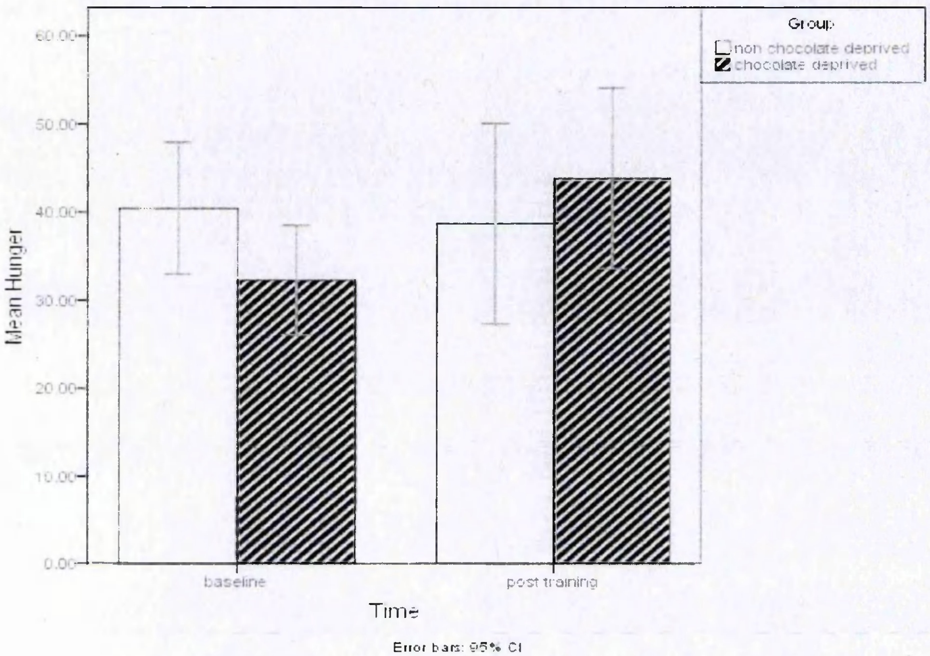
No group differences in rated hunger at baseline

Participants rated their hunger when they arrived at the laboratory (time 1) and immediately after completion of training (time 2). At baseline participants in the non chocolate deprived group provided the highest rated hunger [non chocolate deprived 43.33±2.14, chocolate deprived 38.56±23.03]. However that there were no significant group differences in reported hunger [$U=155.00$ $p=0.336$].

Rated hunger decreased following training

Following training both groups rated their hunger to be lower, however there was no significant reduction in rated hunger between time 1 and time 2 [$Z=-1.794$ $p=0.073$]. Mean ratings show that non chocolate deprived participants had the highest ratings of hunger post conditioning. However there were no significant group differences in rated hunger at time 2 [U=165.00 p =0.496] [Figure 5.14]

Figure 5.13:



Mean (±SD) rated hunger at baseline and post conditioning.

No group differences in baseline ratings of the US

Baseline ratings of the US revealed that participants perceived the chocolate to be pleasant (chocolate deprived 78.35±1.18, non chocolate deprived 78.35 ±1.18). No group difference were found in rated pleasantness [*U=128.5 Z=-0.55 p=0.956*]. Mean ratings of desire to consume more of the US demonstrate that participants wanted to consume more of the chocolate after initial tasting [chocolate deprived = 67.65 ±1.82, non chocolate deprived74.53 ±1.21) . No group differences were found in regards to report desire to consume more of the US at baseline [*U*=112 Z=-0.312 *p*=0.755]

Both groups found the US to be less pleasant following training

Following training participants ratings of US revealed both groups perceived the chocolate to significantly less pleasant [non chocolate deprived Z=-3.063 *p*=0.002; Chocolate deprived Z=-2.747 *p*=0.006]. No group difference were found in rated pleasantness [*U=112 Z=-.312 p=0.774*]. Mean ratings of desire to consume more of the US demonstrate also decreased [chocolate deprived z=2.315 p=0.21, non chocolate deprived z=-2.156 p=0.031]. No group differences were found in regards to report desire to consume more of the US at baseline [U=106 Z=-0.316 p =0.604]

Baseline evaluation showed equal preference for symbols

Table 5.9 displays the number of times each symbol was chosen during the baseline evaluation tasks. A Friedman ANOVA was calculated for each group comparing initial preference for the symbols which would later be associated with 0, 10%, 50% and 90% reward. There were no significant differences in the number of times any symbol was chosen in the control group [Chi Square x^2= 2.839 p =0.417]or the chocolate deprived group [Chi Square x^2=3.090 p =0.378].

Table 5.9:

Reward Contingency	0%	10%	50%	90%
Non Chocolate Deprived	4.137 ± 1.35	5.647±3.22	6.529± 3.24	5.412±3.083
Chocolate Deprived	4.157±0.88	5.59± 2.69	6.18±2.98	5.82±3.05

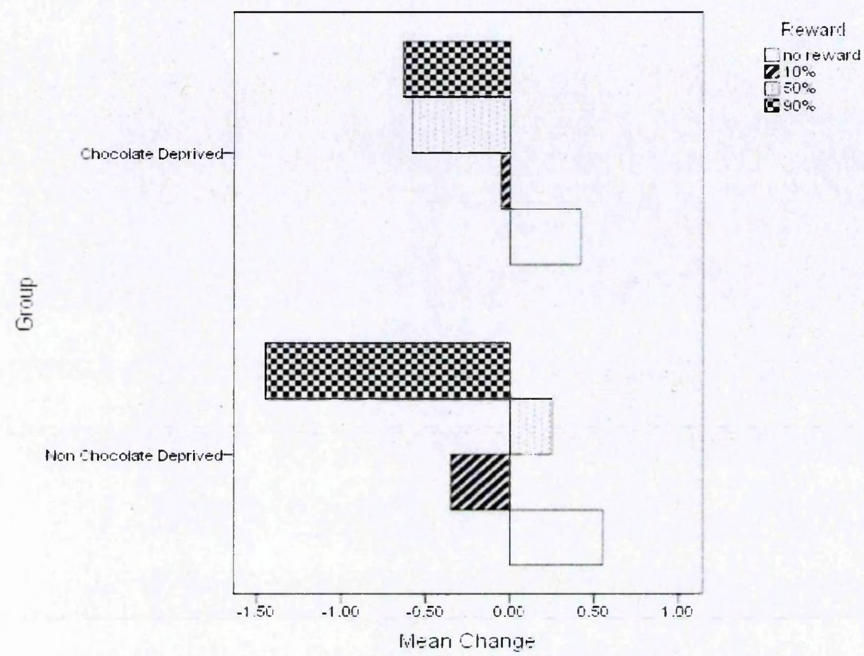
Mean (±SD) times CS stimuli was chosen at baseline

Change in preference post training

Figure 5.14 demonstrates a linear trend for preference change scores following training. Both groups chose symbols associated with 90% reward more frequently training. While symbols which had not been paired with reward during training were chosen less frequently following training. Friedman ANOVA was calculated to examine the overall change in preference scores for each of the symbols used during training. This revealed a significant changes in preference [Chi-square $x^{2=}$6.982 df = 3 p =0.072 one tailed p =0.036]. A Friedman ANOVA was then calculated for each experiment group. Analysis provided evidence for preference learning in the non chocolate deprived group [Chi-square $x^{2=}$9.536 df =3 p = 0.023] . Wilcoxon signed rank tests revealed that symbols paired with 90 reward were chosen more frequently post training than those associated with no reward (Z= -2.467 p =0.007). Symbols paired with 90% reward were also chosen more frequently than those paired with 10 %(Z=-1.929 p =0.027) or 50% reward (Z=-2.215 p

=0.0135). However there was no evidence of learning for the chocolate deprived group [Chi-square x^2= 28.073 df =3 p =0.490].

Figure 5.14



Mean change in symbol preference following training for each group

In line with the previous experiment preference learning was also analysed using weighted planned comparisons (Brunstrom, Downes and Higgs, 2001). A one way ANOVA confirmed that there was a significant difference between the contrast scores for the control group in a two tailed test [t (64) =--2.63 p =0.016 (one tailed p =0.008] and reveals a linear trend within the data. Although the data is representative of a linear trend this did not reach significance for the chocolate deprived group [t (64) =-1.162 p =0.249].

Contingency awareness

At the end of the study participants were informed which symbol they had chosen most frequently during training and were asked to state "why they preferred this symbol". Most participants provided a response which indicated that their symbol choice was based on an aspect of the symbols visual appearance; no participants stated that their choice had been based on the fact that this was the most frequently rewarded symbol.

In total 9 participants (4 in the chocolate deprived group and 5 in the non chocolate deprived group) demonstrated a degree of awareness that the training session had involved conditioning. However no participants were able to explicitly identify which symbol had been most rewarded during training (was there any symbol which you were asked to consume a chocolate more frequently after viewing, if yes which symbol?) This demonstrated that participants did not fully understand the purpose of the experiment and were not explicitly aware of the reward contingency pairing between US and CS.

5.3.3.5 Performance on the Attentional Blink Task

Table 5.10 displays the mean (±SE) percentage accuracy at reporting targets on the AB task. The following section will break down the analysis of the AB data in regards to overall accuracy (trials where both target content was reported), percentage of attentional blinks (trials where T1 was correctly reported but not T2) and ability to report T1 and T2 independently.

Table 5.10:

Percentage Accuracy	Trial Type	Chocolate Deprived	Non Chocolate Deprived
Overall Accuracy	0%	46.52±0.578	44.24±0.043
	10 %	53.33±0.057	48.33±0.038
	50%	50.00±0.044	43.32±0.034
	90%	55.42±0.045	47.72±0.042
AB	0%	57.37±0.06	41.25±0.05
	10 %	72.22±0.05	51.77±0.06
	50%	65.74±0.062	50.86±0.05
	90%	64.85±0.07	44.72±0.06
T1	0%	64.53±0.071	58.68±0.56
	10 %	68.81±0.735	59.93±0.058
	50%	58.23±0.62	53.70±0.052
	90%	68.27±0.67	62.67±0.061
T2	0%	61.80±0.53	59.78±0.065
	10 %	30.97±0.29	30.44±0.029
	50%	32.93±0.031	29.72±0.027
	90%	69.21±0.054	63.61±0.059

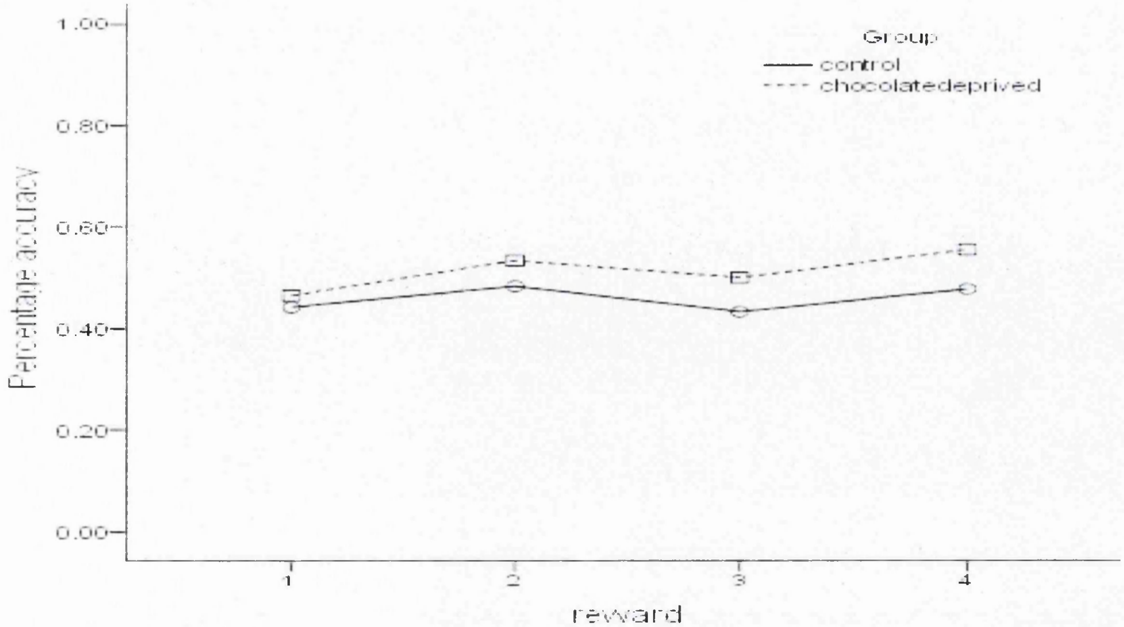
Mean (±SE) percentage accuracy on AB task [Overall accuracy is when both T1 and T2 were correctly identified Blinks are when T1 was correctly identified but T2 was incorrectly identified. T1 accuracy is the correct report of T1. T2 is the correct report of T2]

A mixed design 4 (reward) x 2 (group) ANOVA with conducted to establish if accuracy differed across the T2 conditions. but also to compare the group's performance on the task. T2 reward was the within subjects factor (0, 10, 50, 90) and the between subjects factor was group (non chocolate vs. chocolate deprived). The dependent variable was overall accuracy (percentage). There was a significant main effect of contingency [F (3,111)=3.719 p =0.014] .Although deprivation was associated with higher overall accuracy no significant main effect of group was found [F(1,37)=0.869 p =0.357]. There were no significant interactions between group and contingency [F (3,111)=0.561 p =0.642].

Overall task performance was enhanced when T1 had been paired with 10% or 90% reward during training

Target detection (trials where T1 and T2 content was correctly reported) a significant main effect of training was found [F (3,111)=3.719 p =0.014]. Target detection was significantly affected by the reward contingency that T2 had been paired with during training. This main effect was explored using planed comparisons. Simple contrasts revealed that target detection improved when T1 content had been paired with 10 % [F(1,37)=5.045 p =0.031]or 90% reward[F(1,37)=4.805 P=0.035] compared to those which contained non reward symbols. These effects were replicated for 90% rewarded trials. Although percentage accuracy was higher for trials where T1 had been paired with 50% reward compared to T1 which had not been rewarded; these differences were not statistically significant [F(1,37)=0.230 p =0.634]. Ability to successfully recall both targets on when T1 had been paired with 50% reward was significantly impaired compared to 90% rewarded trials [F(1,37)=12.59 p =0.001] However accuracy on trials where T1 had been paired with 10% rewarded trials did not significantly differ from those which contained symbols paired with 50% reward [F(1,37)=0.581 p =0.451]. There were also no significant differences in reporting targets associated with 10% and 90% reward [F (1, 37) =0.131 p =0.719].

Figure 5.15

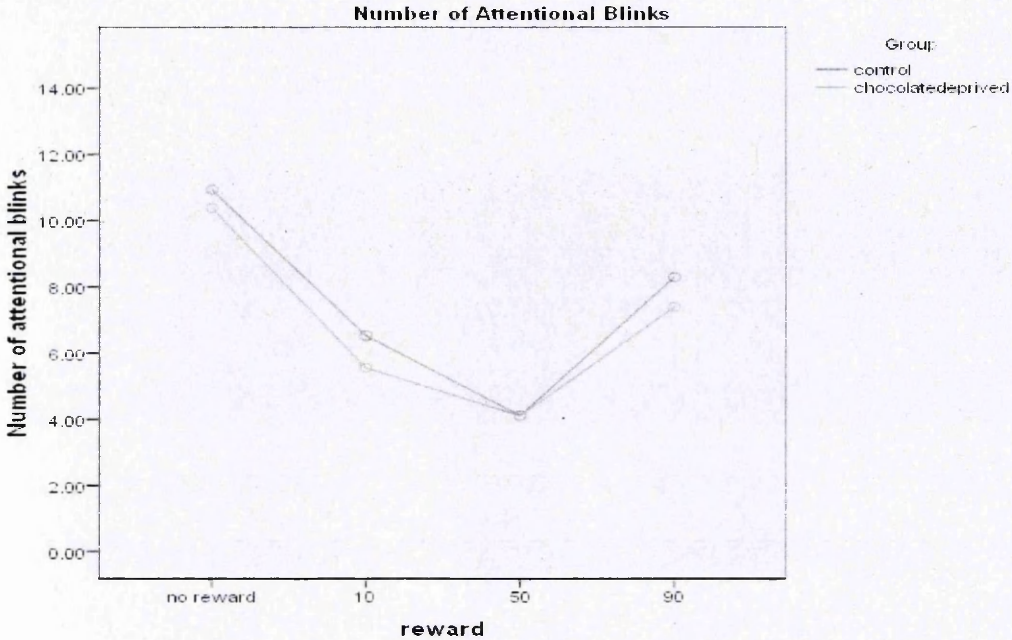


Mean accuracy (%) of correctly reporting the content of T1 and T2 on AB trials

The percentage of attentional blinks decreased when T1 had not been paired with reward during training

Figure 5.17 shows the mean percentage of attentional blinks for both groups and indicates that both groups "blinked" more trials when they contained symbols which had not been paired with reward. Analysis indicated that there was a main effect of training [F (3,99) =22.749 *p* =0.000] . Planned comparisons using simple contrasts revealed that there significantly **more** attentional blinks in trials where T1 had not previously been associated with reward. When T1 had been paired with no reward it was T2 was blinked significantly more times compared to trials which had been paired with 10% reward [t (35)=4.381 P<0.00], 50% reward[*t (35)=3.93 P<0.00*] and 90% [*t (35)=8.959 P<0.00*]. Although there were more blinks for trials where T1 had been paired with 90% reward compared to 10% reward this difference only reached significance only at the one tailed level [t(35)1.738 P<0.045]. T2 was blinked most frequently in the no reward condition, significantly **less** blinks were found when T1 had been paired with 50% reward compared to those paired with 10% [*t(35)=-2.708 P=0.011*] and 90% reward [*t (35)=--5.56 p <0.00*]. These relationships remained significant after applying bonforoni's corrections.

Figure 5.16



Mean percentage of incorrect trials which were classified as "blinks" (T1 correctly reported. T2 incorrectly reported) for each group

No group difference in target detection

Although deprivation was associated with higher overall accuracy no significant main effect of group was found [$F(1,37)=0.869$ $p=0.357$]. Similarly there were no group difference in the number of attentional blinks [$F(1, 33)=0.364$ $p=0.551$], recall of T1 [$F(1, 34)=.539$ $p=0.468$] or recall of T2 [$F(1,33)=.0.235$ $p=0.63$].

The non chocolate deprived group were more accurate on control trials

The AB task contained a number of trials where T2 appeared more than 8 stimuli after T1, these trials were control trials as they would not generate an attentional blink [Table 5.11]

Table 5.11:

Trial Type	Chocolate Deprived	Non Chocolate Deprived
0%	41.25±0.23	57.37±0.25
10 %	51.77±0.27	72.22±0.22
50%	50.86±0.24	65.74±0.26
90%	44.72±0.24	64.85±0.27

Mean (±SE) percentage accuracy at reporting distant targets

Training did no significantly influence performance on control trials, [F (3, 105)=2.347 p =0.077]. Equally there was no significant interaction between reward and group [F(3,105)=0.159 p =0.923]. However analysis revealed that the non chocolate deprived group had significantly higher accuracy on control trials [F(1,35)=10.310 p =0.003].

Training only influence task performance if participants were efficient target detectors

The raw data from this experiment showed that participant's ability to detect targets during the AB task varied dramatically between individuals [minimum and maximum scores on trials varied from 11% to 84% accuracy. Participants were allocated into either a high detection or low detection group based on a median split of mean attentional blink performance (average percentage of correct trials across the four trial types). 17 participants were allocated into the high detection group and 17 into the low detection group. Independent t-tests confirmed that accuracy was significantly higher in the high detection group compared to the low detection group [t(32)=-6.501 p =0.00] (high detection group mean percentage accuracy 62.25% compared to 36.01%). The only significant group differences in demographics were found in regards to BMI; low target detectors were found to have significantly higher BMI [t(31)=2.369 p =0.0024]

Table 5.12

Trial Type	Chocolate Deprived		Non Chocolate Deprived	
Target Detection	*High*	*Low*	*High*	*Low*
0%	59.70±0.05	31.87±0.09	56.18±0.034	32.30±0.06
10 %	73.90±0.35	30.48±0.04	60.77±0.03	35.90±0.04
50%	62.30±0.04	36.33±0.52	53.34±0.03	33.30±0.42
90%	68.30±0.05	41.11±0.04	59.83±0.04	35.65±0.05

Overall accuracy (T1 and T2 correct) across the four trial types

Mixed model ANOVA was conducted individually for the high detection and low detection groups. This was to establish whether reward paring of T2 was still a valid influence on performance after controlling for participants performance on RSVP tasks. For the low detection group there was no main effect of reward contingency [$F(1,15)=0.023$ $p=0.882$]. This indicates that when participants were generally poor at reporting target content, the degree to which T2 was rewarded did not influence performance. No significant interaction was found between reward and group [$F(1,15)$ 1.313 $p=0.270$]. No main effect of group was found[$F(1, 15) = 0.121$ $p=0.733$].

The same analysis was conducted for the high detection group. Here a main effect of reward contingency was established [$F(1,15)=4.736$ $p=0.044$] . Planned comparisons revealed that accuracy was significantly higher when T1 had been paired with 90% reward than no reward [$t(16)=-1.531$ $p=0.145$ one tailed] , these effect was replicated for 50% rewarded trials [$t(16)=-3.448$ $p=0.003$ one tailed]. Participants in this group were also significantly more accurate at reporting the content in trials where T1 had been paired with 10% compared to 50% rewarded trials [$t(16)=4.301$ $p=00.1$] . These effects were replicated for non rewarded trails [$t(16)=-2.868$ $p=0.11$]. There was no difference in performance between 10% and 90% rewarded trials [$t(16)=0.674$ $p=0.510$]. Participants accuracy remained consistent across trials which contained non rewarded T1's and 50% rewarded T1[$t(16)=0.355$ $p=0.727$ p] . The interaction between reward and group was verging on significance [$F(1, 15) = 3.469$ $p=0.082$. The main effect of group was also verging on significance [$F(1, 25) = 3.744$ $p=0.072$].

5.3.3.6 Electrophysiological correlates of cue saliency

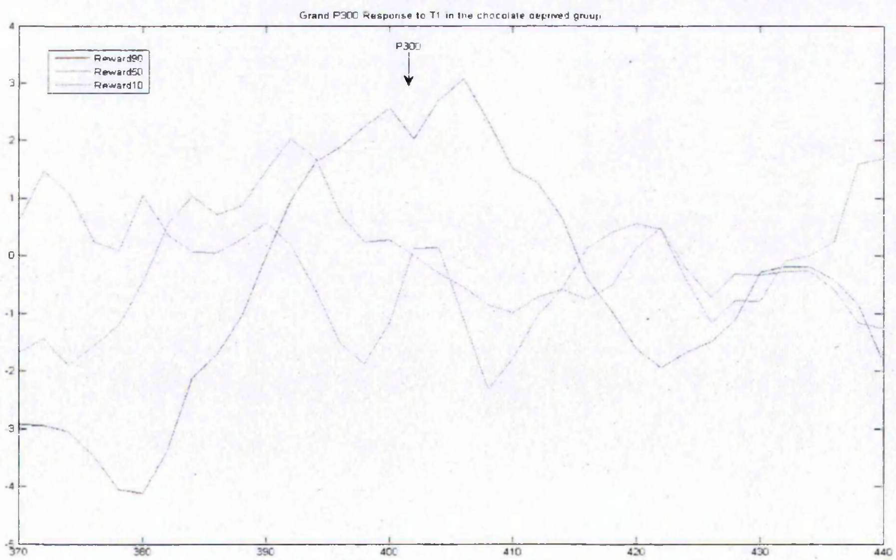
Again the epoch of interest in this analysis was P300 . Figure 5.19 shows grand average P300 responses for each group (averaged across all electrodes) for all trials correct AB trials. Table 5.13 shows the mean peak amplitude of P300 averaged across central, frontal and parietal regions

Table 5.13:

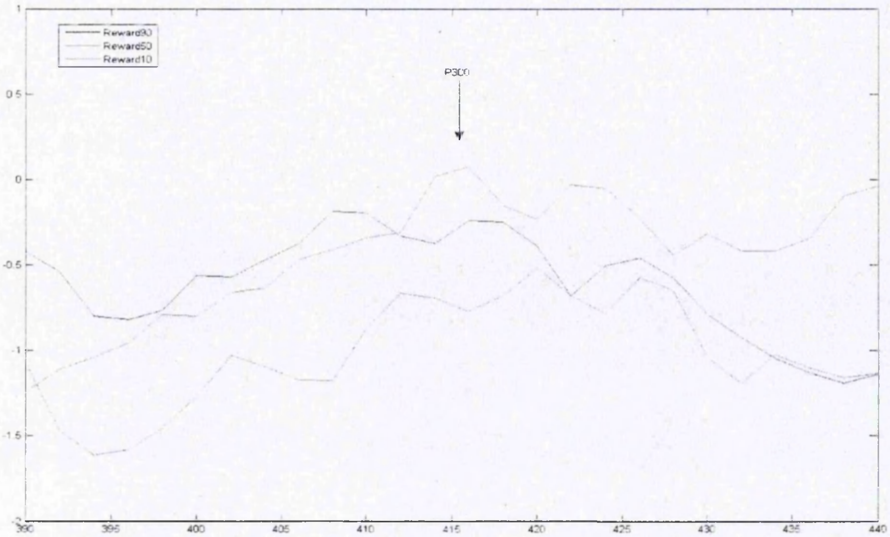
Region	Stimulus	Non Chocolate Deprived Group	Chocolate Deprived
Frontal	10%	2.69±2.97	8.21±10.43
	50%	2.28±3.22	5.481±6.09
	90%	2.06±2.69	11.94±12.56
Central	10%	1.15±1.17	4.83±6.73
	50%	1.29±1.15	3.57±3.65
	90%	1.62±0.87	4.73±4.76
Parietal	10%	1.33±2.63	7.67±7.47
	50%	1.40±1.92	6.61±5.79
	90%	2.29±2.33	10.62±13.66

Mean Peak amplitude (±SD) of P300 collapsed across frontal, central and parietal electrodes

Figure 5.17:



(a) Grand average P300 amplitude (epoch 250-350) for the chocolate deprived group collapsed across all electrode sites



(b) Grand average P300 amplitude (epoch 250-350) for the non chocolate deprived group collapsed across all electrode sites

Training did not influence P300 responses

Although P300 response was higher for 90% and 10% rewarded symbols. Analysis revealed that training did not have a significant influence on P300 response F (2, 26) =0.917 p =0.413].

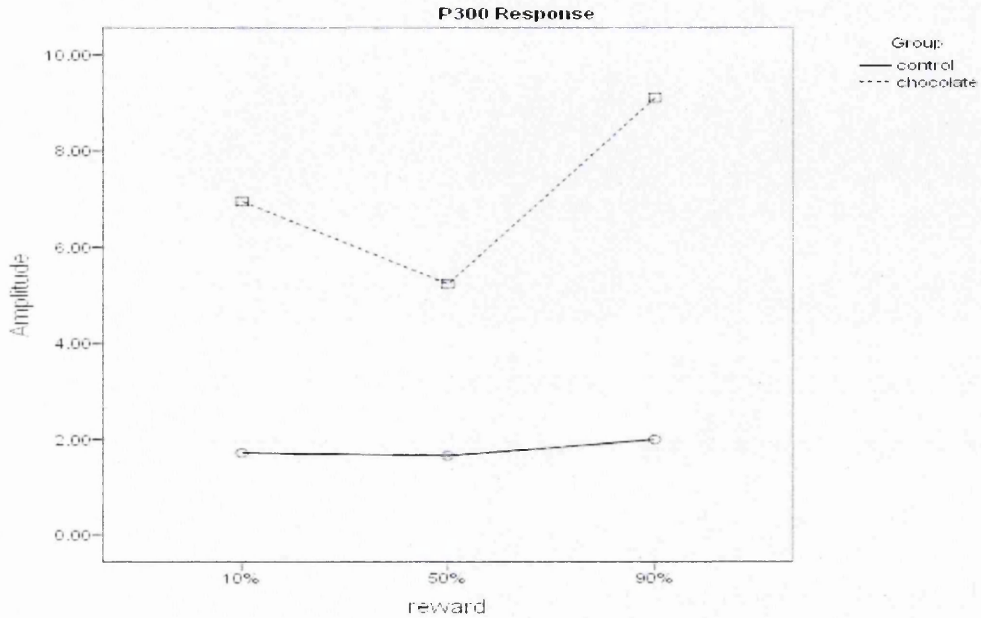
P300 amplitude was higher in chocolate deprived participants

Analysis revealed a significant main effect of group [F (1, 13) =22.245 p =0.001] . Peak amplitude of P300 was significantly higher in the chocolate deprived group. There was no significant interaction found between training and group [F (2, 26) =0.646 p =0.533].

A significant interaction was also ground between sagittal site and group [F (2, 26) =3.152 p =4.373 p =0.024] . This showed that chocolate deprived group had significantly higher P300 responses at left, central and right electrode sites compared to the no chocolate deprived group [Left t(13(-4.011 p =0.002, central t(13)=-2.781 p =0.017, right t(12)=-3.604 p =0.004]. Comparison of within group P300 responses at each sagittal site revealed that in the control group P300 was significantly higher at right electrode sites [right compared to left, t(8)=--2.623 p =0.034], right compared to central t(8)=3.100 p =0.017]. There was no difference in responses at left or central electrode sites in this group [t(8)=0.738 p =0.485]. In regards to the chocolate deprived group P300 response remained consistent across all sagittal sites [p >0.05].

There was no interaction found between sagittal site and training group [F (4, 52)=135.663 p =0.530].

Figure 5.18:



Mean P300 amplitude based on reward and group

P300 did not differ across coronal electrode sites

There was no significant main effect of coronal electrode site [F (2, 26) =1.802 p =0.0.187]. Likewise coronal site was not found to significantly interact with group [F (2, 26) =0.413 p =0.00].

Note : As in Experiment 4 the ERP data was additionally collapsed across anterior electrode sites (F7/8,F3/4,FP1/FP2), central sites (FC5/6,T7/T8,C3/C4) and at posterior electrode sites (P7/8,P3/4,01/02). However this analysis did not add anything to the previously reported findings so will not be reported.

5.3.4 Discussion

Cue preference data in this study replicated the findings of Experiment 4. Following training participants changed their preference for symbols in a linear manner; this is that they increased preference for symbols which had been paired with 90% reinforcement. Whereas rated preference decreased for symbols paired that had not been paired with reward or had been paired with lower reinforcement. Again the data collected in this study suggests that preference for symbols paired with 50% reward remained fairly stable. Although analysis on the overall data set showed significant preference change, no evidence of preference learning was found when the chocolate deprived group data was examined independently. The mean data for this group indicates that participants who had been asked to deprive themselves of chocolate prior to testing had a tendency to increase preference for all rewarded symbols. This change was largest for the cues associated with 90% and 50% reward. Restriction of chocolate intake appears to have made any symbols paired with chocolate reward (CS+) motivationally salient for this group. As in Experiment 4, the majority of participants reported no explicit insight to of reward contingencies used during training. This strengths the argument purposed by Hogarth et al. (2010) that cue conditioning is an automatic and unconscious process.

The behavioural findings from the AB task indicate that targets which had been paired with 10% and 90% reward had higher incentive value. This experiment predicted that when T1 contained CS+ this would reduce the ability to report T2. However this experiment demonstrated that T1 content had the opposite effect. Having a salient T1 appeared to induce hyper vigilance which was reflected in more efficient processing of T2 content. Both groups were the most accurate at reporting the content of T2 when the target preceding it had been paired with paired with high or low reward during training. Chatton et al. (2010) found similar effects in a study exploring how smokers detected T2 content when T1 contained either a smoking related (CS+) or nicotine cue (CS-). When T1 contained a smoking cue the AB effect was attenuated; Chatton et al. (2010) proposed that when T1 content had high incentive value this induced hyper vigilance. Heightened awareness of drug related cues is likely to lead to the content of T2 being processed earlier. Further support for the claim that the behaviour effects of this study are a consequence of hyper vigilance can be drawn from the fact that accuracy of identifying T2 was significantly influenced by the reward contingency associated with T1. Participants were most likely to recall the content of T2 when T1 had previously been paired with 90% reward. This effect cannot be attributed to differences in symbol complexity as the same numerical symbols were used for T1 across all trial types. This effect was not found in experiment 4 which used the same numerical stimuli set (but in the position of T1).

This data does not directly support the findings published by Piech et al (2010) who found that participants were less accurate at reporting the content of T2 when T1 contained a food image. However there are important methodological differences between the AB used experiment 5 and that used by Piech et al. (2010). This AB task could be considered to be less complex that that used in Piech et al. (2010) who's RSVP stream was made up of photographic distracters (landscapes). Participants were required to identify the content of T1 was a coloured image (food image, romantic image or neutral image) and the rotation of a landscape appearing at T2. The paradigm used by Piech and colleges (2010) was more multifaceted that that used in this experiment; both in terms of stimuli content but also in regards to task demands. If the AB task used in this experiment was modified so that both T1 and T2 contained complex symbols that may lead to closer replication of Piech et al. (2010) findings. It is also important to note that Piech et al. (2010) only found a reduced ability to report the content of T2 when participants were hungry. Food images were not found to be related to worse performance in the non fasted session, rather the pattern of results for the saited session appears to mirror that of those found in this study and by Cannon et al (2010). When saited, participants were more accurate at reporting the content of T2 when T1 had contained a food image. Therefore the effects outlined above could be dependent on motivational state.

Again the extent to which reward contingency becomes a manipulator of performance appears to be effected by individual's ability to detect symbols in a RSVP stream. The reward paring of T1 only influenced T2 accuracy when participants were "efficient target detectors". This supports the claims by Dux and Marois (2008) that they are individual differences in regards to attentional blink performance, they regard individuals who are efficient target detectors as being "non blinkers". This suggests that these individuals are more proficient at ignoring distractor items on that attentional blink task which subsequently enhances their ability to detect targets. The implications for these findings are discussed in more detail in the general discussion section of this chapter.

This data does appear to demonstrate that when a CS+ was paired with 10% and 90% during training it developed incentive salience. Although no significant main effect of reward was found in the electrophysiological data for experiment 5; larger P300 amplitudes were found for CS+ which had been paired with 10% or 90% reward. It is likely that the main effect of reward contingency did not reach significance in this sample due to the limited size of the data set. As the ERP analysis was conducted only on participants which had 10 valid trials for each of the cue conditions (ones during which participants correctly identified both targets and had not blinked or moved during recording) the sample was subsequently smaller than what was used in Experiment 4 (N=28). Another disparity between the electrophysiological data collected in this experiment and that collected in experiment 4 is the main effect of group. For this experiment rewarded symbols evoked significantly higher P300 amplitudes in the chocolate deprived group. A possible interpretation of this is that symbols paired with chocolate reward elicited increased saliency for this group of participants. However whether this is down to chocolate deprivation remains debatable as these group differences were not established in the previous experiment.

Key Findings

1) Training again influenced preference for novel stimuli
2) Salient T1 content induces hyper-vigilance, this leads to quicker processing of T2.
3) CS+ associated with 10% and 90% reward have increased incentive value

Experiment 6

Can conditioned cues increase craving?

5.4 Introduction

The previous two experiments demonstrated that the incentive value of neutral cues can be manipulated through reinforcement. When neutral cues were associated with differential levels of chocolate reinforcement they were able to command increased attention on an AB task compared to control cues (Experiments 4 and 5). Cues which were paired with high (90%) and low (10%) contingencies elicited significantly greater attentional resources than cues paired with 50% and no reward. This was demonstrated on both an electrophysiological and behavioural level. These effects remained consistent regardless of the position of the CS target during the AB task. Although both Experiments 4 and 5 provide evidence towards biased processing of rewarded cues (similar to what is proposed in the addiction literature) neither experiment explored how the cues affected eating behaviour or food craving

Field and Cox (2008) proposed that both attentional bias and craving are important in the maintenance of addictive behaviours. To summarise, when substance users are exposed to salient cues in their environment these act as signals of substance availability. This expectancy directly influences craving and drug seeking behaviour which in turn heightens vigilance for substance related cues. Applying this model to eating behaviours, the presence of food cues in the environment should lead to biased processing (as seen in Experiments 4 and 5) but also increased craving or food seeking.

Previous work has demonstrated the effects of conditioned cues on eating behaviour (Birch et al. 1989; Cornell et al. 1989; Petrovich et al. 2007b; Weingarten and Elston 1990; Weingarten and Watson 1982). Participants that have learnt to associate novel cues with food display conditioned responses such as craving and increased intake to the CS+ in subsequent presentations. The majority of research exploring cue reactivity in humans is based on the premises that individuals are already display conditioned responses to familiar food cues. Cornell (et al. 1989) showed that participants trained to associate a novel cue with chocolate reinforcement increased their reported craving on later exposures to the when the CS +. Similarly Gucht et al. (2010) study of cue-induced chocolate craving, successfully trained participants to associate the presence of one tray (C+) with chocolate reward and one tray with the absence of chocolate reward (C-). At the end of training the CS+ elicited stronger craving for chocolate than the C-. Kober et al. (2010) also explored how cognition can influence cue elicited craving. In this study participants (heavy smokers, chippers and non smokers) were trained to associate a neutral cue with one of two coping strategies. For one group the cue was used to generate thoughts about the immediate consequences of consuming the pictured substance (e.g. it will be rewarding), whilst for the other group this same cue was associated with focusing on the long term consequences of consuming the item (e.g. it will be detrimental to my health). The cue subsequently primed participants to use one of two coping strategies prior to them rating how much they would like to consume the cigarette or food item displayed on screen. Focusing on the long term consequences of behaviour significantly reduced reported craving for food items across all participants, whereas a reduction in nicotine craving was only demonstrated in smokers.

These findings provide justification for predictions that the CS+/CS- cues used in our training paradigm may be able to influence craving in different ways. Experiment 6 will present participants with a neutral cue paired with reward or no reward and then asked them how much they desire to consume a specific food item. It is predicted that when participants are primed with a CS+ this will induce highest craving. This is based on the assumption that participants will have learnt through conditioning that the CS+ is predictive of immediate reward. The opposite effect on craving would be predicted when participants were primed with a CS- (cue that was not paired with reward).

In line with the previous experiments in this chapter electrophysiological recordings will be taken during the cued craving task. This will allow assessment of cortical activity in response to CS+ and CS- cues. In addiction research P300 has been used as a functional substrate of cue induced craving. This approach have shown that drug cues elicit increased P300 responses in alcohol dependent populations (Elhers et al. 2003; Genka and Shostakovich, 1983; Hermann et al. 2000, 2001; Namkoong et al. 2004), smokers (Littel and Franken 2007; McDonough and Warren, 2001; Warren and McDonough et al. 1990), heroin dependent populations (Franken et al. 2003, Lubman et al. 2003, 2007), cocaine users (Franken et al.

2008;Van dal larr et al.2003). This enhanced P300 response is thought to reflect increased attentional resources allocated to processing of salient cues.

There are few studies that have attempted to indentify the ERP correlates of food craving. Most work has examined the influence that hunger and satiety has on ERP responses to food cues but not craving per se (Carretie, Mercado and Tappia, 2000; Hachl et al. 200; Plihal et al. 2001). Food deprivation (hunger) is associated with increased ERP responses to food images. More recently Njis et al (2008) expanded this area of work examining the ERP correlates of hunger and craving in obese and normal weight adults. This study found no differences in ERP responses based on BMI but did find that P300 amplitude correlated with self reported hunger but not craving (Njis et al. 2008). However another study by the same group did establish significant correlations between P300 amplitude and self reported craving (Njis et al. 2009). An explanation for these disparities is that craving was measured using self report which in itself is often problematic. Self reported craving is susceptible to underreporting and the effects of social desirability (e.g. obese participants under reporting craving). Consistent with Nijs et al. (2009) Franken et al. 2011 found a positive association between P300 amplitude and reported craving. Franken et al. (2011) found that higher P300 amplitudes were found in response a geometric pattern that had been paired with the sweet taste. This effect was generally observed among the frontal central electrode locations and is interpreted as evidence that conditioning allows neutral symbols to acquire increased motivation relevance. Franken's research like Nijs (2010) found a positive association between P300 amplitude and reported craving.

A potential limitation of Experiments 4 and 5 is that during training session the US may have been devalued as chocolate was consumed during training. Here training will be altered so that half of the participants receive a reward which they will consume immediately. While the other half will "win" the reward which they will be able to consume on completion of the study. This is consistent with previous research exploring cue induced craving, Hogarth et al. (2006) uses a method which allows participants to "win" points towards obtaining their desired substance (Hogarth et al. 2006). This experiment will therefore additionally aim to establish whether the effects of the conditioning (as seen in Experiment 4 and 5) are dependent on participants consuming chocolate reward at time of training.

5.4.1 Methods

5.4.1.1 Participants

Fifty participants (33 female and 17 male) completed the behavioural tasks in this study with EEG being recorded for a subset of 20 individuals Participants were randomly allocated into one of two training groups. Half of the participants (N=25) completed training where they consumed a portion of chocolate every time they found a red rectangle. While the other half (*N*=25) "won" a portion of chocolate which they were informed that they could eat at the end of the experiment. Participant recruitment adhered to the selection criteria set out in the general methodology section. The mean age of participants was 22.94±3.31 years and mean BMI was 20.746 ±4.11.

5.4.2.2 Design

The main between subjects IV was training group (Eat vs. Win chocolate). An additional between subjects IV was reward contingency this contained four levels (0%, 10%, 50%, 90%) reward). The DV in this study was reported craving.

5.4.1.3 Stimulus Materials and Equipment

The craving task was run on E-prime and participants responded to trials using a six button response box. The conditioning paradigm was adapted from Brunstrom et al. (2005) and was run using visual basic.

Novel Stimuli

The novel stimuli in this experiment are outlined in detail in the general methodology section. A total of 4 symbols were used as novel neutral stimuli, 3 were used as CS (symbols 1, 2 and 3) and one CS- (symbol 4).

Conditioning Paradigm

The conditioning procedure used in this study is outlined in detail in general methodology section and Experiment 4. However Participants in the WIN training group were asked to add their chocolate to a "win pile". They were told that they consume this chocolate at the end of the study.

Evaluation Task

The evaluation tasks were identical to those used in Experiments 4 and 5.

Craving Task

The stimuli used in the craving task consistent of 40 colour photographs; 20 food images were used which could be categorised into two food categories – 10 high energy dense chocolate items (e.g. chocolate buttons, chocolate brownie) and 10 high energy savoury items (e.g. burger, fries). A further 20 images of alcohol related items were used as control stimuli. All stimuli used in this task had been previously rated in a pilot study as being representative of each of the three categories. These items were chosen as they were deemed representative of foods and drink items that could be consumed by the participant at "that moment" i.e. not food that needed to be cooked. All images were matched in regards image complexity and jpeg size. The images had a height of 5cm and width of 5 cm. The task was based on that used by Kober et al. (2010). Each trial began with presentation of the CS (Chinese symbol) this was shown for 2000 ms. The symbol was followed by either a food or an alcohol picture which was shown for 6000 ms. Participants asked to rate their current desire to consume the food item shown on a rating scale from 0-5 (0= not at all 5=very much). This rating was done using a response box. In total there were 160 trials. Participants completed 10 practice trials where they were required to rate desire to consume low calorie food items.

5.4.1.4 Procedure

As in Experiments 4 and 5 all participants were required to complete an online questionnaire prior to their attendance in the social laboratory. From this questionnaire TFEQ-R scores were used to select suitable participants for the experiment. Participants had to score less than 5 on the TFEQ-R to be eligible for this study. Written informed consent was obtained from all participants prior to the commencement of the study.

On arrival participants gave written informed consent and completed the first mood rating questionnaire. The researcher then introduced the computer based task which assessed baseline evaluation of the experimental stimuli, this required participants to make paired comparisons of the stimuli selecting each time the stimuli they most preferred. On completion of the baseline evaluation task, participants tasted and rated the US (this was based on a single portion). Participants were then introduced to the training stage of the experiment. Participants were instructed that they would be required to find red rectangles hidden in the boxes on screen. Depending on which experimental group participants were assigned to they would sometimes be instructed to eat a sweet when they found a red rectangle or alternatively be told to add a sweet to their win pile.

Following conditioning participants were asked to taste and rate the US one final time; they then completed a final stimuli evaluation task (this task was identical in design to task used for baseline evaluation). Afterwards participants completed a final mood rating questionnaire and those which were in the EEG subgroup were prepared for EEG recording. The setup of electrodes took approximately 10 minutes during which participants completed the DEBQ questionnaire. Participants who did not have EEG recorded also spent 10 minutes completing these scales.

Participants introduced to cued craving task by completing 10 practice trials. Participants were told that they would be viewing a number of food and drink images and that their task would be to state how much they wished to consumed to the item on screen at this very moment. Participants made their responses on a 6 button response box. . After completing the practice trials EEG was recorded for the cue craving task. This task took on average 20 minutes. At the end of the study participants completed a measure assessing awareness of training after which they were fully debriefed.

5.4.1.5 Electroencephalographic (EEG) Recording

Voltage recordings were performed on the scalp in accordance with the 32+2 system in Fp1-2, AF3-4, F3-4-Z, F7-8, FC1-2, FC5-6, C3-4-Z, CP1-2, CP5-6, T7-8, P3-4-Z, P7-8, PO3-4, O1-2-Z, plus CMS and DRL as reference channels from a 32+2 channel elastic Electro-cap. The bandwidth was set between 0.3 and 40 Hz with a sampling rate of 16384 Hz. All electrode impedances were at or below 50 kΩ. The EEG was continuously collected during the attentional blink task and edited off-line with BESA (Version: research 5.3). EEG was recorded from 300 ms prestimulus to 400 ms post stimulus. After baseline correction ERP mean waves were calculated for each participant at each scalp site for each trial type. Based on visual inspection of the grand average waveform P300 was defined as the average amplitude within the 258 to 408 ms time window. In order to reduce noise only participants with more than 10 valid trails for each condition were included in the analysis. This resulted in

17 participant's data being included in the subsequent analysis. For the purpose of this experiment statistical analysis was restricted to three electrode positions [Fz,Cz, Pz]. This restricted electrode set was based on previous ERP analysis exploring the relationship between the P300 response to drug cues and craving (Lubman, 2008).

5.4.2 Data Handling and Analysis

Kolmogorov-Smirnov and Shapiro Wilks showed that some of the dependent measures in this study were non normally distributed. These variables included ratings of symbol preference (0-10), demographic data (TFEQ_R, Chocolate consumption and BMI), Ratings of US. Finally participant's response times on the craving task were also non normally distributed. The appropriate non parametric analysis were conducted on these factors.

The dependent measures of interest in this study include change in preference for symbols following training, baseline and post training ratings of hunger, US ratings and craving task responses. In regards to the electrophysiological data the main measure of interest was peak amplitude of P300. This was calculated as the mean peak voltage value for each trial type (10%,50%,90% and no reward) occurring between the epoch of 258-408ms. This is the time at which the content of T2 would be processed.

Stimuli preference scores was calculated as the difference between the number of times each CS was chosen during evaluation and conditioning. Therefore stimuli preference score could range from -10 and +10. A negative score was represented that the CS stimuli was chosen more times after conditioning.

As with the previous two experiments Mann- Whitney U tests were used to examine if the two groups measured in regards to demographic characteristics and psychometric measures of appetite (e.g. BMI, habitual chocolate consumption, restrained eating (DEBQ_R and TFEQ_R), external eating, emotional eating and age). As rated hunger was normally distributed in this experiment; Paired T-tests tests were used to compare baseline and post training ratings of hunger. Whilst paired t-tests were used to examine changes in reported hunger from baseline to post conditioning. Wilcoxon signed rank tests were conducted to compare rated pleasantness of the US before and after training, and also the desire to consume more of the US. Mann-Whitney U tests were used to compare group ratings of these variables.

Differences in preference ratings of stimuli at baseline were assessed using a mixed design 4 x 2 ANOVA. The within subjects factor was CS symbol (0%,10%,50% and 90%) and the between subject factor was group (win vs. eat). The DV was the number of times each symbol was chosen at baseline.

Preference learning was then assessed using a 4 x2 analysis of ANOVA. Again this had CS symbol as a within subjects factor and experimental group as between subjects factor. The DV was change in preference (calculated as the difference between initial and evaluation preference score).

Based on previous analysis of the data (Brunstom, 2001) collected by the conditioning task used in this experiment. Planned comparisons were conducted to further examine the preference learning. A weighted comparison was made for each comparison rating across subject. Accordingly the contrasts weights of - 1, 0 and 1 were applied to 10, 50 and 90 contingency data. Which derived a separate contrast score for each participant? The P value obtained from this analysis was dived by 2 to obtain a P value relevant to a one-tailed hypothesis. A t-test with corrected error (see Judd et al. 1995) was then conducted for each contingency and experimental group.

In order to establish if training had any effects on reported craving a mixed design 2 X 3 X 4 ANOVA was conducted. This compared craving across the three stimuli items (chocolate items, non chocolate and alcohol). Reward Contingency of the preceding cue was an additional within subjects' factor which had four levels (0, 10, 50, 90). Group was a between subjects factor (win vs. eat). DV was reported craving. Spearman's correlations were conducted to examine the correlates of craving these are reported to one tailed significance (unless otherwise states).

Craving data was also examined based on trait craving. A median split was used to classify participants into high or low cravers based on their mean craving scores. The 2 X 3 X 4 ANOVA outlined above was conducted for each group.
The ERP data is based on recordings from a subset of participants (N=20), EEG was recorded only when participants were completing the cued craving task The electrophysiological data was prepared and analysed as described in the general methodology section. The effect of reward on peak voltage of P300 was examined using a mixed 4(reward) x (item) x 3(reward) x 3(site) x 2(group) ANOVA. The between subjects factors were reward contingency (0,10,50,90); item type (chocolate , non chocolate and alcohol), electrode site (Fz, Pz and Cz). The between subject factor was group (win vs eat). The DV was P300 response. Mauchly's test indicates

that the assumption of sphericity was upheld for all main factors therefore a correct F value will not be reported. Main effects were explored using planned t-tests.

5.4.3 Results

5.4.3.1 Demographics

Mean demographic data for the two training groups are shown in Table 5.14. During recruitment experiment groups were matched in regards to level of restrained eating as measured by TFEQ_R and reported chocolate consumption. Both groups had low TFEQ_R scores (<5) and consumed chocolate at least on a daily basis or more. Mann Whitney U tests confirmed that there were no significant differences in dietary restraint [$U(48)$=257.500 Z=-1.093 p=0.274] or habitual chocolate consumption [$U(48)$=624.00 Z=-0.290 p =0.772]. There were no significant differences in between the groups BMI [U (48)=299.00 Z=-0.290 p =0.772] or age [t (48) =0.894 p =0.376].

Table 5.14

Group	**Win (*N*=25)**	**Eat (*N*=25)**
Age (years)	22.52±3.6	23.36±3.91
Dietary Restraint (TFEQ_R)	4.52±2.58	3.64±1.87
BMI (kg/m^2)	21.39±4.72	20.09±3.38
Gender (female: male)	17:8	16:9
Habitual Chocolate Consumption	5.24±0.88 (daily)	5.40±1.61(daily)
Habitual Alcohol Consumption	4.44±1.94 (twice weekly)	3.92±2.02 (twice weekly)

Mean (± SD) of demographic characteristics for each group

5.4.4.2 Training Phase

No group differences in rated hunger at baseline

Participants were required to rate their hunger when they arrived at the laboratory (time 1) immediately after completion of training (time 2) and following the craving task (time 3). Mean data revealed that at baseline hunger was generally low [<40.00] There were no significant group differences in reported hunger at baseline [*t* (48) =0.593 *p* =0.55].

Rated hunger increased following training in the win group

Following training there was a trend for the both groups to rate hunger as being higher than at baseline [win: 37.72±0.47 compared to 46.84±0.53, eat 22.98±0.46 compared to 25.69 ±0.51]. Rated hunger did not significantly increase from time 1 to time 2 for the eat group[*t*(24)=-0.848 *p* =0.405]. However the WIN group displayed a significant increase in hunger following training [*t*(24)=--2.245 *p* =0.034]. There were no group differences in rated hunger at time point 2 [*t* (48)=-0.207 *p* =0.837]. Both groups rated hunger at time 3 was significantly higher than time 2 [eat *t* (24)=--2.22 *p* =0.036, win *t*(24)= -2.403 *p* =0.024]. Although rated hunger at time point 3 was highest in the win group there were no significant difference found between the two groups [*t* (48)=0.-0.340 *p* =0.735]. Over the course of the study both groups were found to have significantly increased rated hunger (baseline compared to T3) [eat *t* (24)=-2.702 *p* =0.012, win *t* (24)=-4.090 *p* =0.00]. Effect sizes reveal that this increase was significantly larger for participants in the WIN group.

No group differences in baseline ratings of US

Baseline ratings of the US revealed that participants perceived the chocolate as being fairly pleasant [Eat M=71.36± 0.33. Win M=66.52 ±0.45]. No group differences were found in rated pleasantness [*U* (48) 269.00 *Z*=-0.382 *p* =0.702]. Mean rated desire to consume more of the US demonstrate that participants wanted to consume more chocolate after initial tasting [Eat 69.80±0.35, Win 65.00±0.54]. No group differences were found in rated desire to consume more of the US [*U* (48) 255.5 *p* =-0.382]

Following training only the win group rated the US as being less pleasant

Both groups demonstrated a decreased in how pleasant they rated the chocolate post training ; however this was only found to significant in the EAT group [Eat group, *Z* (25)=-1.739 *p* =0.082 one tailed *p* = 0.041, Win group *Z* (25) -1.33 *p* =0.183]. No significant group differences were found between the groups ratings [*U* (48)=275.5 *Z*=-0.248 *p* =0.804] .Rated desire to consume more of the US only significantly decreased following training in the EAT group. [Eat group Z (25) =-2.966 p =0.003, win group Z (25) =-1.589 p =0.112]. There were no significant differences in reported desire to eat more of the US following training [U (48) =269.5 p =-.372]. To summarise this data indicates that the US was only perceived as being significantly less pleasant and desirable in the training procedure which required participants to consume the US. These effects are likely to be caused by satiation as participants consumed around 60 mini smarties across the course of training. This again equated to approximately 300 calories.

No differences in the number of times each symbol was chosen during baseline evaluation

Table 5.15 displays the number of times each symbol was chosen during the baseline evaluation tasks. An ANOVA was calculated for each across the data set to compare initial preference ratings of the symbols. There was no significant differences in the number of times each symbol was chosen at baseline There was no interaction between symbols and group [$F(3,144)=1.468$ p =0.226]. No significant main effect of group was found [$F(1,48)=2.608$ p =0.133].

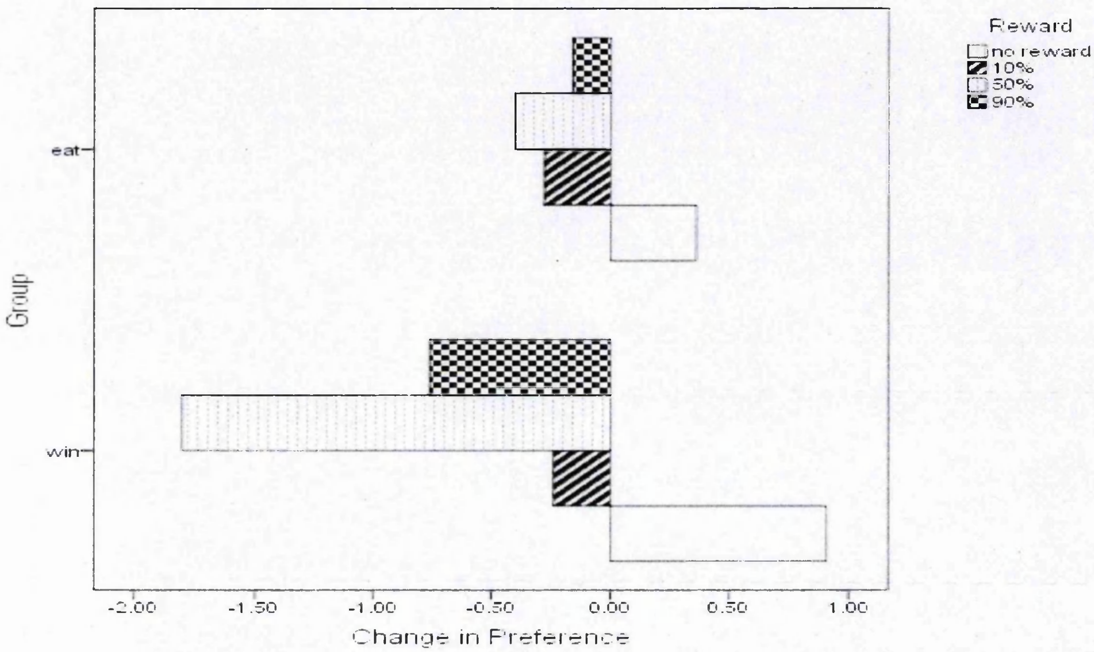
Table 5.15 :

Reward Contingency	0%	10%	50%	90%
Eat(N=25)	4.62±1.033	5.68±3.21	5.00±3.49	5.40±3.11
Win (N=25)	4.17±1.05	5.00±3.32	6.72±2.61	5.76±3.19

Mean (±SD) number of times symbols was chosen at baseline

Change in rated preference of symbols following training in the eat group

Figure 5.19:



Mean change in symbol preference following training for each group

To examine if the training procedure change the number of times symbols were chosen following training a ANOVA was conducted . This revealed that the training had a significant effect on symbol preference [$F(3,144)=3.708$ $p=0.013$]. There was no interaction found between reward and group [$F(3,138)=1.278$ $p=0.284$]. However a main effect of group was found [$F(1,48)=4.357$ $p=0.042$].

The main effect of group was explored by running a separate ANOVA for each group's preference change data. Reward contingency was only found to influence preference for symbols for the group which consumed chocolate during training [$F(3,72)=5.089$ $p=0.003$]. Planned contrasts revealed that in this group; symbols were selected more frequently if they had been paired with chocolate reward during training [no reward vs. 10% $t\ (24)=2.416$ $p=0.024$, no reward vs. 50% $t\ (24)=3.562$ $p=0.002$, no reward vs. 90% reward $t\ (24)\ 2.638$ $p=0.014$]. Although rated preference was highest for symbols which had been paired with 90% reward actual preference change score was not found to be significantly different from symbols paired with 50% [$t(24)=1.337$ $p=0.194$] or 10% rewarded symbols [$t(24)=-0.723$ $p=0.447$. Change was higher for symbols paired with 10% reward than those paired with 50% reward [$t(24)=1.915$ $p=0.067$ one tailed $p=0.034$]. No significant main effect of reward was found for the WIN group [$F(3,72)=0.368$ $p=0.776$].

A weighted comparison of ratings for each subject was made with the contrast weights -2,-1, 1, 2 being applied to 0%, 10, 50, 90% reward. A one way ANOVA confirmed that there was a significant difference between the contrast scores [$F(3,199)=4.690$ $p=0.003$]. The analysis revealed a linear trend within the data, indicating that symbols with low reward were liked less following training, whilst symbols paired with higher reward contingencies were liked more

Participants had limited awareness of training procedure

As with previous experiments participant's awareness of reward contingency and experimental demands was assessed via an awareness questionnaire. Participants were informed which symbol they had chosen most frequently during training and were asked to state "why they preferred this symbol". As in previous experiments in this chapter the majority of participants provided a response which indicated that their symbol choice was based on an aspect of the symbols visual appearance. No participants stated that their choice had been based on the fact that this was the most frequently rewarded symbol.

In total 12 participants (7 in the WIN group and 5 in the EAT group) demonstrated a degree of awareness that the training session had involved conditioning. However no participants were able to explicitly identify which symbol had been most rewarded during training (was there any symbol which you were asked to consume a chocolate more frequently after viewing, if yes which symbol?) This demonstrated that participants did not fully understand the purpose of the experiment and were not explicitly aware of the reward contingency pairing between US and CS.

5.4.3.3 Performance on the cued craving task

Table 5.16 shows the mean craving scores for each of the three item categories. This indicates that reported craving remained similar across the three stimuli categories.

Table 5.16

Item	**Eat**	**Win**
Chocolate	3.40±1.44	3.89±0.83
Non Chocolate	3.31±1.03	3.44±0.98
Alcohol	3.82±0.94	4.00±0.83

Groups Mean±SD reported craving for items shown during cued craving task

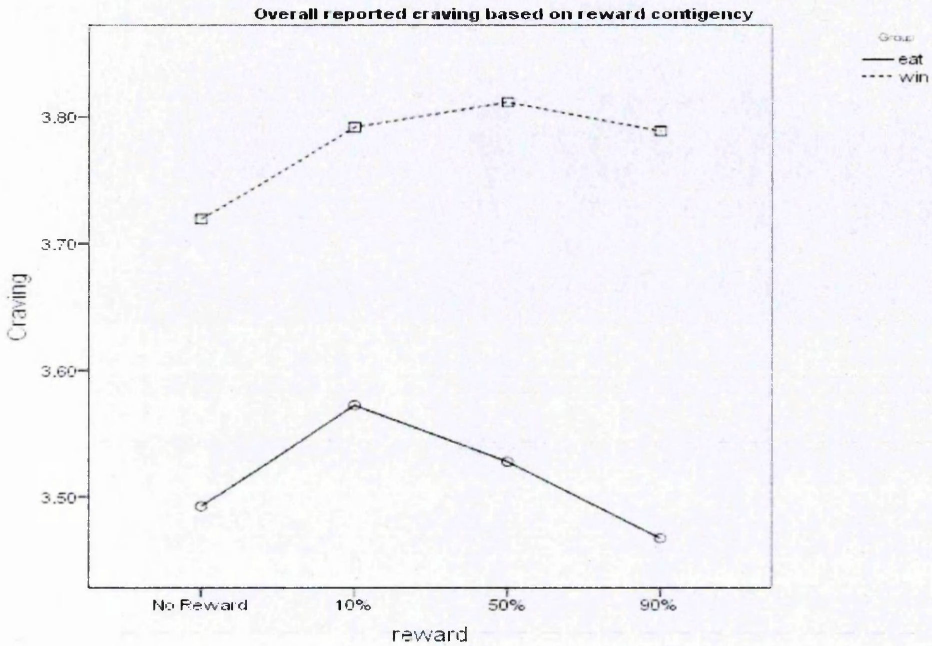
In order to establish if training had any effects on reported craving a Mixed 2 (group) X 3 (item) X 4 (reward) ANOVA was conducted. This compared craving across the three stimuli items (chocolate items, non chocolate and alcohol). Reward Contingency of the preceding cue was an additional within subjects' factor. This had four levels (0, 10, 50, 90) . Group was a between subjects factor (win vs. eat). There was a significant main effect of reward contingency [F (3,144) =4.266 p =0.006]. Analysis also revealed a main effect of item type [F(2,96)=3.269 p =0.042]. However no significant main effect of group was found [F(1,48)=1.637 p =0.207].

Training influenced craving

Analysis revealed that training had a significant influence on reported craving [F (3,144) =4.266 p =0.006] [Figure 5.22]. When participants were primed with a symbol which had not been rewarded with chocolate during training they reported lower craving. Overall craving for items preceded by CS- was significantly less than items which had been primed with 10% (t(49)=-2.723 p =0.0045) or 50% [t(49)=-2.217 p =0.0155] rewarded cues .Although craving was higher in response to 90% cues (3.63±0.73 compared to 3.60±0.73) this did not reach significance [t(49)=-0.925 p =0.123 one tailed]. Participants reported craving was similar in response to 50% and 10% rewarded cues [t(49)=0.742 p =0.231]. These ratings were significantly higher than those elicited by 90% reward [10% t(49)=2.073 p =0.0215, 50% t(49)=-

1.822 p =0.0375]. There was no significant interaction found between reward and group [$F(3,144)=1.980$ p =0.120].

Figure 5.20



The effect of reward contingency on reported craving during the cued craving task for each group.

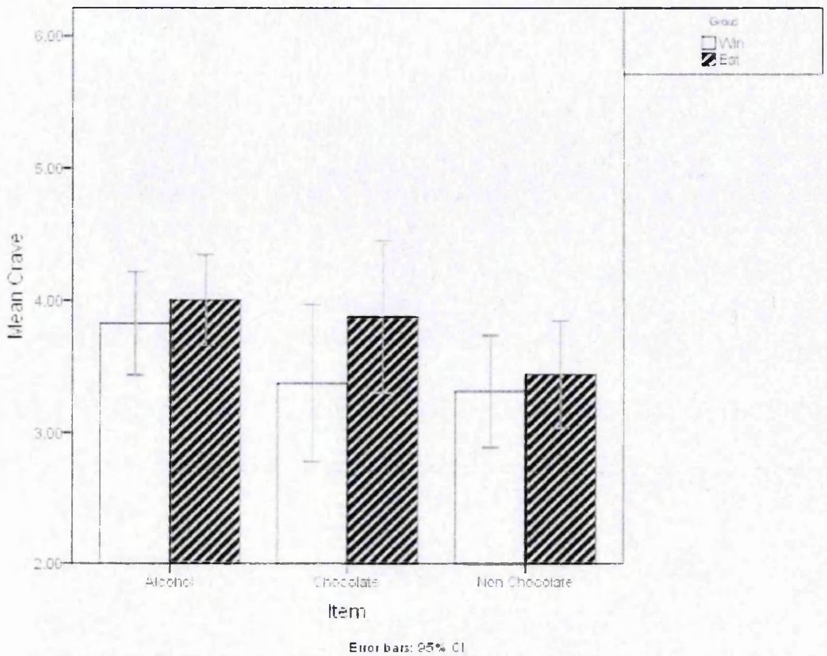
Trend towards higher craving in the WIN group

Although craving was higher for participants who completed the "WIN" training (Figure 5.22), this difference was not significant found [$F(1,48)=1.637$ p =0.207].

Highest reported craving was for alcohol items

Analysis revealed a main effect of item type [$F(2,96)=3.269$ p =0.042]. Figure 5.23 indicates that craving was highest in response to alcohol items and chocolate items. Paired t-test confirmed that there were no significant differences in craving for alcohol and chocolate items [$t(49)=0.992$ p =0.163 one tailed]. Craving was significantly lower for non chocolate items compared to alcohol items [$t(49)=2.997$ p =0.0025]. The difference in craving for chocolate and non chocolate items was verging on significance [$t(49)=1.667$ p =0.051]. Finally no interaction was found between item category and group [$F(2,96)=0.421$ p =0.658] or item category and reward [$F(6,288)=0.819$ p =0.556].

Figure 5.21



Group mean (±SD) reported craving for alcohol, chocolate and non chocolate items

Correlates of craving

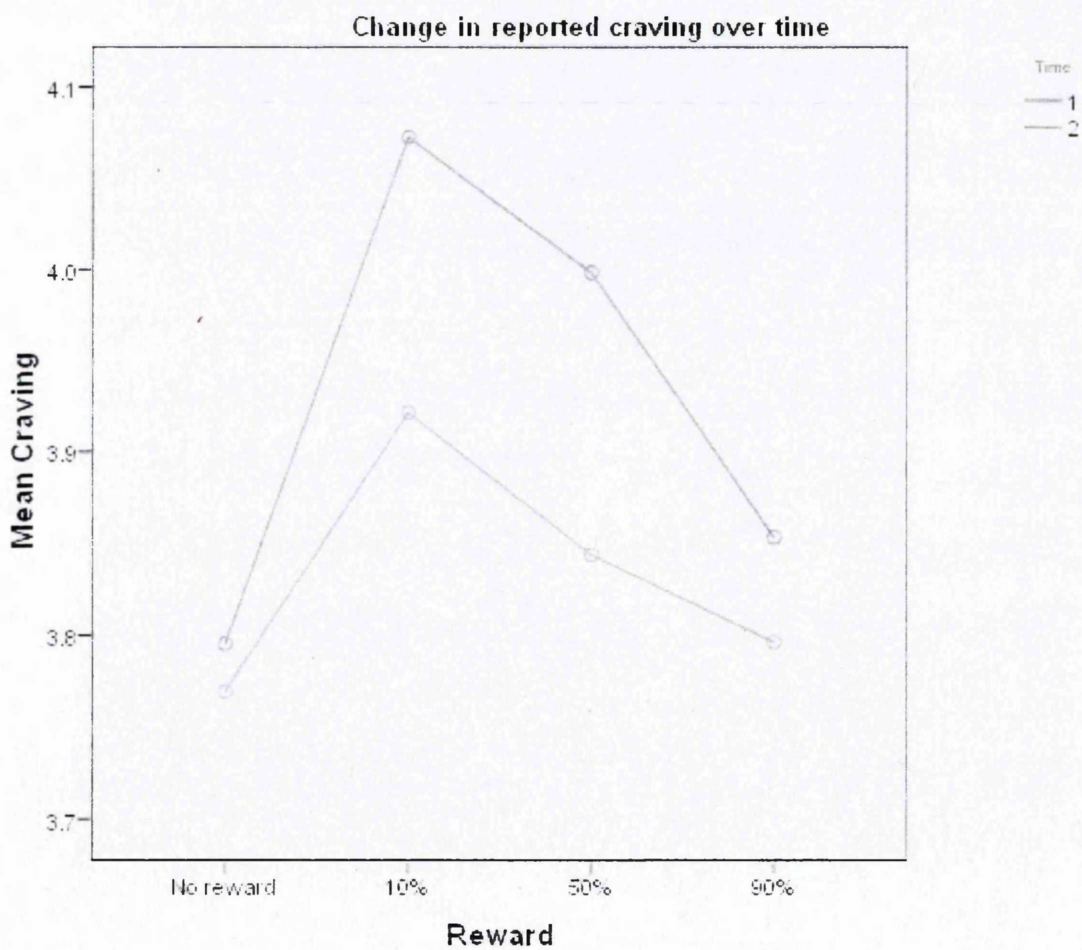
Spearman's correlations revealed that participants who reported high chocolate consumption had a tendency to report higher craving for alcohol items during the task [r=0.297 p =0.037] but lower chocolate craving [r=-0.306 p -=0.031).

Participants who had highest ratings of desire to consume more of the US after training had significantly higher craving for chocolate items on the cue-craving task [r=0.476 p =0.001]. However desire to eat more chocolate after training did not predict craving for any other item on the task [p >0.05]. Higher mean reported craving for chocolate items on the task predicted high craving for non chocolate items [r=0.576 p =0.00] but lower alcohol craving [r =-2.80 p =0.049]. FCQ scores were found to be a positive predictor of BMI [r=0.558 p =0.031]. There was no other significant relationships found between BMI and any craving measure [p >0.05].

Time course analysis

Time course analysis was conducted on rated craving to establish whether rated desire to consume the item shown changed with time. As this analysis was exploratory it was only conducted on the subset of participants which had undergone EEG recording during the task (N=20). Mean rated craving was calculated for the first 50 and last 50 trials on the craving task. A 2 (group) x 4(reward)x 2(time) ANOVA was conducted with mean craving as the DV. Consistent with previous analyses there was a main effect of reward $F(3,54)=2.96$ $P=0.04$ and no main effect of type $F(1,18)=0.108$ $P=0.746$. Although reported craving did decrease across the course of the experiment, these changes in ratings were not significant ($F(1,18)=0.948$ $P=0.34$. No significant interactions were established.

Figure 5.22



Change in reported craving from time point 1 (first 50 trials) and time point 2 (last fifty trials)

5.4.3.4 Electrophysiological correlates of craving

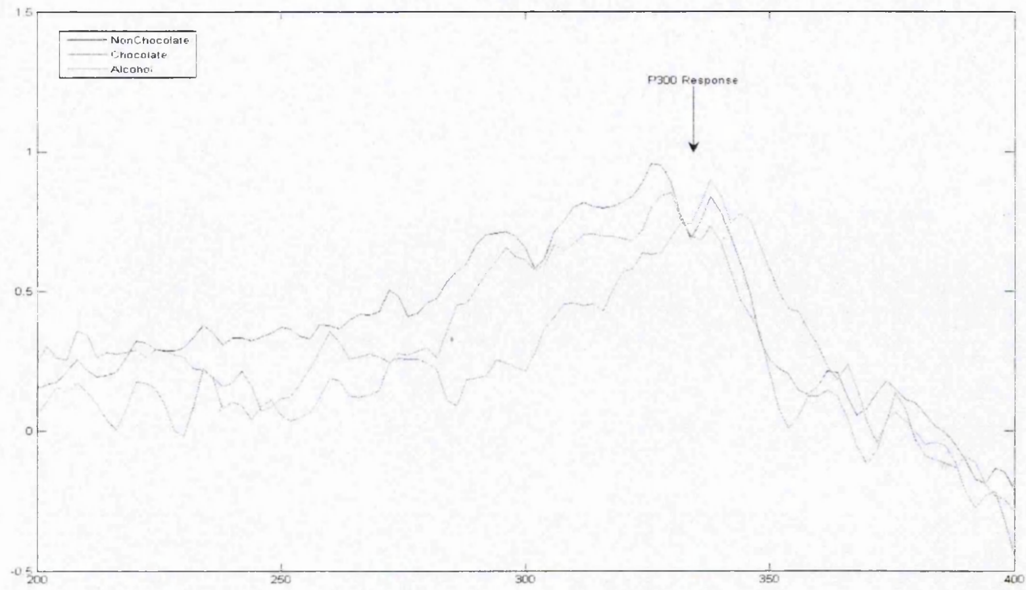
Mean peak amplitude of P300 was calculated at three electrode sites (Fz, Cz, Pz) were (Table 5.17). These 3 electrode sites were chosen as they were shown to display highest P300 responses in previous cue-craving research (Lubman et al. 2008). Table 5.19 demonstrates that across the three items the eat group consistently had strongest P300 responses to the items primed with a non rewarded cue. No significant correlations were found between P300 responses and item craving ($p > 0.05$).

Table 5.17

Stimulus Type	Reward	Win Group	Eat Group
Alcohol	No reward	2.169±4.86	6.33±4.38
	10%	2.1932±2.47	2.57±4.51
	50%	5.0510±3.25	-0.78±4.96
	90%	4.25±3.92	1.98±6.9
Chocolate	No reward	1.37±4.48	6.51±11.49
	10%	1.97±3.93	3.90±3.85
	50%	0.49±3.19	3.075±6.19
	90%	0.54±6.08	4.89±3.41
Non Chocolate	No reward	2.16±4.86	6.34±4.38
	10%	2.19±2.46	2.57±4.51
	50%	5.05±3.25	0.78±4.96
	90%	4.25±3.93	1.98±6.92

Groups mean (±SD) peak P300 response averaged across Fz, Pz, Cz for each item type

Figure 5.23



Grand Average for wave forms (averaged across all electrode sites) during the P300 Epoch in response to alcohol, chocolate and non chocolate stimuli

No difference in P300 response to items on the craving task

Although the magnitude of P300 was higher in response to food pictures (high calorie chocolate, high calorie non chocolate) compared to alcohol stimuli (Figure 5.22). Analysis revealed that item type did not significantly affect P300 response [F (2, 30) =0.265 p = 0.769]. Equally there was no interaction found between stimuli type and group [F (2, 30) =2.311 p =0.117] or stimuli type and training [F (6,90)=0.097 p =0.997]

Training influenced P300 response only in the eat group

Analysis revealed that was no main effect of training [F (3, 45) =2.138 p =0.109]. However a significant interaction was found between training and group [F (3, 45)=3.564 p =0.021]. For the WIN group P300 response to stimuli remained consistent; this is that it was not influenced by reward contingency that the preceding cue had been paired with. However figure shows that training was a relevant correlate of P300 for individuals who ate the US during training. Paired sample t-tests showed that there were no significant differences in P300 found between any reward contingency in the WIN group [p >0.05]. However for those who completed the EAT training, non rewarded trials elicited significantly higher P300 responses than items cues with 10% [t (7) =1.919 p =0.096 one tailed p =0.048] or 50% rewarded symbols [t (7) =2.965 p =0.021 one tailed p =0.0105]. Although this amplitude was higher than what was elicited by 90% rewarded cues this differences did not reach significance [t (7) =-1.312 p =0.231]. A lower P300 response was seen when stimuli were preceded by cues which had been paired with 50% reward during training; this was significantly lower than the response to 10% rewarded cues [t(7)=2.190 p =0.065 one tailed p =0.032] but not significantly lower than the response to 90% rewarded cues [t(7)=-1.276 p =0.243]. No other significant differences in P300 response were found [p >0.05]. This results appear to indicate that items were preceded by a non rewarded or 90% cues received the most visual attention in the EAT group.

HigherP300 amplitude at frontal electrodes

There was a significant differences in P300 amplitude across the three electrode sites [F (2,30)=9.527 p =0.001]. The highest P300 amplitude being recorded at the Fz electrode, this was significantly higher than P300 at Cz [F (1,15) 27.744 p =0.000] and Pz[F (1, 15) =5.062 p =0.040]. There were no differences found in P300 at Cz and Pz [F (1, 15) =2.530 p =0.133]. Increased amplitude at frontal sites is consistent with the hypothesis that it is the orbital frontal cortex which first detects salient cues.

A significant interaction was also found between electrode site and group [F (2,30)=4.729 p =0.016]. Independent t-test showed that P300 response in the EAT group was significantly higher at Fz compared to the WIN group [t (15) =-2.129 one tailed p =0.025]. No group difference were found in regards to Cz response [t (15) =-0.838 p =0.415] or Pz response [t (15) =1.207 p =0.246]. For each group P300 at Fz was significantly higher than P300 at Cz [WIN t(8)=3.589 p =0.007, EAT t(7)=3.933 p =0.006). For the WIN group no significant difference found in P300 response at Fz and Pz [t(8)=-0.120 p =0.907] however a higher response was recorded at Pz than Cz [t(8)=-3.125 p =0.014]. For the EAT group P300 at Fz was significantly higher than P300 at Pz [t (7) =2.513 p =0.040], no difference in P300 response was found at Pz and Cz [t(7)=-0.043 p =0.967]. There was no interaction found between electrode site and stimuli type [F(4,60)=0.801 p =0.529] or electrode site and reward

[F(6,90)=0.485 p =0.818]. There were no significant group differences in P300 amplitude [F(1,15)=1.440 p =0.249]

5.4.4 Discussion

The training data in this study replicated the findings of Experiments 4 and 5; indicating that symbol preference can be successfully manipulated through paring with chocolate reward. However evidence of preference learning was only established in participants who had been asked to consume chocolate during training. The WIN group rated symbols that had been paired with the chocolate US as being more preferable. Although the addiction literature has effectively demonstrated that smokers can be trained to associate cues with reward, through pairing a CS with the winning of points which can be used to obtain a desired substance (Hogarth et al. 2006). These effects were not reflected in this experiment's data. Participants who won (but did not consume) chocolate during training did not change their preference for the symbols in a linear manner. This group showed the biggest increase in preference for symbols for which indicated a 50/50 chance of winning a portion of chocolate. The disparity between the effects of this experiment and those found by Hogarth (2006) appear to indicate that conditioned responses to food cues are reliant on intake. However it is important to note that although training did not appear to successfully manipulate symbol preference for the WIN training group, this was the only group to report a significant increase in hunger after training.

In regards to participant's awareness of training demands this experiment directly replicated the findings of Experiment 4 and 5. The data indicated that participants had limited insight into experimental demands or US/CS reward contingency pairing. This again adds strength to Hogarth's (2010) argument that value learning can be an automatic and implicit process. For this experiment the US was changed from chocolate chips to mini smarties. This change was made to establish if the increased salience of symbols paired with 10% and 90% reward on behavioural tasks could be attributed to US devaluation. Despite this experiment using a US that had tasted less rich, participants still decreased their rated desire to consume more of the US and also how pleasant they found the chocolate. This change was only found to be statistically significant when participants had been required to consume chocolate during training. This supports the previous interpretation that participants become saited across the course of training.

Performance on the cue craving task does provide some support that a CS+ prime can elicit higher craving. The behavioural data revealed that the effects on craving did not differentiate on the basis of reward contingency, as all reinforced cues (CS+) were predictive of higher reported craving. Statistically reported craving were only found to be significantly higher when the CS+ prime had been paired with 50% or 10% reward. This finding fits with the idea of temptation as cues which were the least predictive of chocolate reinforcement were found to elicit the highest subjective craving response. Similarly comparison of craving between the two groups indicates that the WIN group had highest craving. Although the main effect of group did not reach statistical significance, this trend does again correspond with expectations that temptation enhances craving.

Priming increased craving for all items shown in the craving task (chocolate, high calorie non chocolate foods and alcohol). Equally P300 responses did not differ based on the item type shown. This effect seems to support work by Robbins and Ehrman (2004) who propose that substance users display equal electrophysiological reactivity to all addictive substances regardless of which substance they are dependent on. Our data also tentatively supports the proposal that there is a phenotype for cue reactivity (Mahler & de Wit, 2010). Mahler and de Whit work indicated individuals who had higher indices of cue induced reactivity from smoking cues also had an elevated response to food cues (Malher and de Wit, 2010). The relationship measures of craving in this experiment were explored; the analysis indicated that chocolate craving was a positive predictor of craving for other food stimuli (non chocolate items) but not alcohol. Chocolate craving was a negative predictor of alcohol craving. This finding in some respects contradicts Mahler and Whit (2010) proposition that the cue reactivity phenotype seen in their research was not underpinned by a general tendency for participants to report high "craving". An additional contradiction to this assumption is that when Experiments 6 behavioural data was categorised into high and low chocolate cravers; high chocolate cravers displayed increased craving for all items shown during the task. Whereas low chocolate cravers highest craving responses were to alcohol stimuli. Alcohol stimuli were used in this task as control stimuli, therefore it was not initially predicted that the CS+ prime would have an effect on craving for these items. However in retrospect the participants sample used in this study were from a undergraduate population, who reported that they consumed alcohol on a regular basis, so it is likely that alcohol stimuli had comparable motivational value to the chocolate stimuli used in this task.

The ERP data in this experiment indicates that reward contingency was only a valid correlate of P300 for individuals who had completed the "EAT" training. This was also the only form of training that successfully manipulated symbol preference. An increased P300 response was found to for items that had been preceded by a 50% reward prime but also those that were primed with a non rewarded cue. This appears to indicate that for this study cues which were associated with no or uncertain reward became the most salient during the cue conditioning task. Increased P300 amplitude was found at frontal sites which is consistent with previous suggestions that the orbital frontal cortex is responsible for the initial detection of salient cues. P300 responses in this area were higher for the EAT training group which again suggests that training had was able to significantly manipulate incentive value of experimental cues. No relationship was found between P300 response and reported craving.

To summarise Experiment 6 is supportive of previous claims that the training paradigm used is able to manipulate the incentive value of cues. However this experiment additionally indicates that preference learning is reliant on intake of the US during training. Conditioned cues can be used to manipulate craving for hedonic items on a cued craving task. This data (in line with Experiment 4 and 5) indicates that cue saliency is not necessarily related to a high reward value and is rather an index of value learning. There is limited evidence from this experiment that craving is reflected in heightened P300 response.

5.5 Chapter Discussion

In summary the findings of this chapter can be applied to aid the understanding of how food cues acquire incentive value. In line with current models of attentional bias, the three experiments in this chapter show that greater attentional resources are allocated to cues which have increased incentive value. Neither of these experiments was able to fully establish what properties make cues salient. The ERP evidence collected across these three studies are consistent in regards to their all indicate cues are paired with 90% reinforcement elicit increased P300 responses (a correlate of attention). However the data from this chapter also appears to indicate that symbols associated with lower reward values have the potential to be equally as salient. A possible interpretation of these findings is that salience is related to value learning, this that any cues which becomes predictive of an outcome (regardless of valence) can develop incentive properties.

This chapter experiments used novel methodology, subsequently there are a number of important methodological considerations that can be taken from this pilot work. The following section will therefore discuss improvements and shortfalls of the tasks used in this chapter.

A consistent finding in Experiments 4 and 5 was that more attentional resources were allocated to CS+ which had been paired with 10% and 90% chocolate reward during training. These symbols also elicited higher P300 responses. One possible account for these effects is that high and low rewarded symbols become salient through US devaluation. A commonality between all three experiments in this chapter is that the US (chocolate chip or smarties) were rated as less pleasant across the course of training. Ratings of US pleasantness decreased by 12.83±0.31 (Experiment 4) and 1.97±0.47 (Experiment 5); reported hunger also reduced in line with this predicted satiation. Interestingly for Experiment 6 the only decrease in US pleasantness was found in the group which had been required to consume the chocolate US during training. This indicates that the probable cause of this devaluation is that participants were required to consume a large number of chocolates during the course of training (45 in total which equates to around 300 calories). This may have made participants feel satiated or even induced feelings of nausea.

Decreased liking for the US is a potential confound that may inadvertently be reducing the effects of preference learning. This has also been implicated as a possible cofounding factor in research using similar training procedures (Brunstrom et al. 2001, 2005). Correspondingly there are a number of publications within the flavour preference learning literature have documented that using a sweet US leads to inconsistent and unreliable "learning" compared to training which uses a unpleasant US (De Houwer et al. 2001 as cited by Brunstrom, 2005; Rozin et al. 1998). Future research could address this issue of devaluation in a number of ways. For instance it could be argued that a savoury US may produce more reliable results, similarly measuring participants reported nausea may allow the researcher to directly quantify if training was making the participants feel unwell. Alternatively future research could aim to explicitly devalue the US prior to training; participants could be asked to eat chocolate to satiation prior to completing the training task. This methodology should in theory strength any devaluation effects seen on later attentional tasks.

Another consistent finding across all three experiments is that participants had low awareness of experimental demands and could not articulate why they had increased preference for the CS+. Although our effects are in line with accounts that value learning is an automatic and implicit process (Hogarth et al. 2010) previous publications have proposed that experimental effects are highly reliant on contingency awareness (Brunstrom et al. 2001, 2005). From this it appears sensible to propose that the effects seen in this chapter could be enhanced if our cue conditioning procedure was able to generate explicit contingency awareness. Future research may aim to address this by training participants to respond to the novel cues over a number of sessions.

The previous literature review outlined a number of robust effects which are associated with food deprivation. It was predicted that manipulating of chocolate consumption via 48 hour chocolate deprivation would have an impact on behavioural and electrophysiological correlates of attention (McDonough and Warren, 2001). In particular it was predicted that enhanced P300 responses would be found in participants who were asked to deprive themselves of chocolate prior to testing; as deprivation was likely to influence the motivational salience of the CS+. However deprivation was only found to enhance P300 response to CS+ in Experiment 5. As Experiment 4 and 5 used similar protocols and measures, caution must be taken when interpreting the enhanced P300 response in chocolate deprived participants from Experiment 5. Retrospectively the methodology used in these two experiments may have been improved by using a within subjects approach. This would allow comparison of evoked P300 amplitude to the CS+ stimuli when participants were deprived and not deprived of chocolate prior to training.

There are also a number of limitations which make it difficult to interpret the true meaning of the ERP data collected in this chapter. P300 has been found to increase when participants are required to make decisions about stimuli (Eduardo et al. 2005). This has possible implications for the AB tasks used in Experiments 4 and 5; elevated P300 response to targets may have been influenced by the fact that all the symbols used during training and in attentional task had similar visual characteristics. This may have reduced any variance seen in P300 response to the three symbols. Equally P300 is also influenced by task difficulty, with greater P300 responses being found on tasks which high levels of cognitive processing (Eduardo et al. 2005). It can also be proposed that more robust ERP effects would have been found if the all participants had undergone EEG recording rather than the subsets used in these experiments. However as these experiments were only an initial exploration that aimed to establish whether these effects could be measured. Identification of these limitations will be beneficial to furthering research in this area.

5.5.1 Summary of main findings

- The training task can manipulate preference for symbols. Symbols paired with 90% reward are liked the most following training, while participant's generally decreased preference for symbols paired with lower or no reward.

- Training effects may be more robust if conditioning was carried out over a number of sessions

- Training is dependent on intake. Experiment 6 showed that participants did not change their preference for symbols if they had "won" the US during training.

- Although 90% rewarded symbols elicit higher P300 responses across trials. Value learning may be important to cue saliency –behavioural performance on attentional tasks was enhanced for symbols paired with low reward. This is also supported by electrophysiological data. It needs to be established whether the training procedure used in this experiment leads to devaluation of the US.

- Devaluation of the US may have resulted in increased attentional resources being allocated to symbols paired with low reward.

Chapter 6

General Discussion

General Discussion

6.1 Aims of the thesis

This thesis set out to explore how attentional bias for food cues related to individual differences in eating behaviour. One objective was to address whether individuals who are hyper-responsive to the presence of food cues in the environment have an increased propensity to gain weight or have an eating style that reflects restraint or disinhibition. Another objective was to understand how food cues in the environment acquire salience, capture attention and influence desire to eat or actual consumption. A full discussion of each study is provided in earlier chapters; here the implication of the findings and how they related to wider issues in overeating are discussed.

6.1.1 *Does the pull of environmental food cues lead to overeating?*

The food processing bias literature denotes that being hyper-responsive to the presence of food cues is characteristic of individuals who have an increased propensity to gain weight (Brignell et al. 2009; Castellanos et al. 2009; Mogg et al.1998; Newman, et al. 2008; Nijs et al. 2010; Piech et al. 2010; Tapper et al. 2008). Experiment 1 extended the current literature by exploring how the pull of environmental food cues related to body weight and disinhibited eating. This study was also one of the first to use the PFS (Lowe, 2009) in a British sample. The results from Experiment 1 provide mixed support for the proposal that hyper responsivity to food cues contributes to weight gain. Obese and overweight respondents had stronger anticipatory desire to overeat in the presence of available food cues compared to those of normal body weight (as measured by the PFS available cues subscale). However no significant relationship was found between the subscales of the PFS and BMI. These subscales did correlate with other self-report measures of overeating and weight gain susceptibility (TFEQ_D, TFEQ_H, DBEQ_Em and DBEQ_Ex). This is consistent with the notion that there is some degree of overlap between the disinhibition measure of the TFEQ and the emotional and external factors of the DBEQ. These measures reflect a tendency to gain weight, subsequently they were all found to predict BMI. Therefore it can be proposed that Experiment 1 demonstrates that individuals who are responsive to food cues in the environment are at risk of overeating if they have poor self regulation and weak dietary restraint .

The power of food scale is a self-report measure of hyper-responsivity to food cues which did not appear to relate to eating style. It is possible that this self-report measure is just not sensitive enough to measure the extent to which cues grab attention as it is not designed to measure attentional bias. To address this, food processing bias was measured using a visual dot probe paradigm. Paying biased attention to food stimuli in the environment is considered to be a normal part of motivated behaviour, such that it makes sense for attention to be pulled towards items or locations that can satisfy needs (Berthoud, 2007; Blundell & Finlayson, 2004; Lowe & Butryn, 2007). Both Experiments 2 and 3 demonstrate that all participants, irrespective of BMI or eating characteristics were quicker at responding to high calorie food items than neutral items on the VDP. A central objective of this thesis was to substantiate the proposition that paying enhanced attention to food cues in the environment is related to overeating. Theoretical explanations of attentional bias strongly outline that biased processing should lead to approach behaviour. Applying this to appetite, individuals who are hyper-responsive to the presence of food cues in the environment should have increased motivation to eat following cue exposure (e.g Kelley and Berridge, 2002). At the time of developing this thesis, this prediction had not been explored in the appetite literature; the majority of publications into FPB are based on correlations between indices of attentional bias and BMI. To address this, Experiment 3 used an attentional retraining paradigm to manipulate FPB. Participants who had been trained to pay enhanced attention to food items on the VDP had a significantly higher calorie intake in a subsequent taste task. Although the effect sizes in Experiment 3 were small, this study does lend support to predictions that paying enhanced attention to food cues increases approach behaviour. Although the difference in calorie intake in this experiment was again small [mean difference 192.87 kcal] it is important to interpret this in the context of normative feeding. Weight gain is often the consequence of an individual overeating by a small amount on a regular basis.

6.1.2 Can indices of food processing bias predict BMI?

Although the results of Experiment 3 demonstrated a direct link between FPB and food intake, the majority of evidence in this thesis provided little conclusive evidence that individuals who were overweight had higher FPB. Equivalent to previous findings, neither experiments in Chapter 3 found FPB to be a strong predictor of BMI (Castellanos et al. 2009; Njis et al. 2010). In fact for Experiment 2 a stronger relationship was found between self reports of heaviest ever BMI and FPB. This supports the work of Caltri et al. (2010) who found FPB measured using a modified stroop task, to be predictive of weight gain over a twelve month period. The weight suppression measure used in this experiment is of significance as it suggests that FPB may be a better predictor of weight gain susceptibility rather than BMI. It can be argued that individuals with high FPB, may consequently develop strong self regulation which enables them to maintain their BMI within a normal range. This may explain why past research has not found strong correlations between BMI and attentional bias. Future research needs to explore if FPB can predict subsequent changes in BMI in individuals who identify themselves as being vulnerable to weight gain. This sample could be recruited through genotyping or by self report. Finally, when reflecting on the findings of this thesis it is important acknowledge that for all experiments participants mean BMI was within the normal range, this is likely to be a result of using a young sample. Larger differences in FPB bias may have been found if experiments had compared obese participants' responses to individuals with normal body weight.

6.1.3. *To what extent is variability in self regulation reflected in attentional bias to food stimuli?*

From the data collected in Chapters 2 and 3 it can be proposed that FPB has an indirect relationship with BMI. This is that the extent to which an individual is driven to overeat by environmental cues appears to be mediated by self regulation. This relationship was initially identified in Experiment 1, which suggested a model of obesity as being predicted by a behavioural combination of high disinhibition and low dietary restraint (TFEQ_R only). Experiment 2 sought to establish whether differences in disinhibition were reflected in FPB, this was novel as no previous publications had categorised participants in terms of TFEQ_D. Experiment 2 successfully demonstrated that individuals with high TDEQ_D scores were significantly faster at responding to probes replacing high calorie food items. This group were also found to have higher BMI. Experiment 2 provided further support for the proposal that the expression of FPB in overeating is mediated by self regulation, as individuals who were easily disinhibited by the presence of food cues had highest indices of attentional bias and BMI. Much of the previous literature exploring FPB has focused on individual differences in dietary restraint (Boon et al. 2000; Hollit et al. 2010; Mogg et al. 1998; Pothos et al. 2008). Restrained eaters restrict their calorie intake in a conscious attempt to maintain their body weight; this is another aspect of self regulation which was implicated in this thesis. Experiment 3 found that ad libitum calorie intake during the taste task was dependent on individual's dietary restraint. Participants low in dietary restraint who were trained to attend to food cues on the VDP ate significantly more following training. This was interesting as these effects show that dietary restraint had an impact on food intake even though participants were unaware that calorie consumption was being measured

During this research project there has been a surge of research exploring the role of impulsivity in FPB and obesity(Hou et al. 2011; Loeber et al. 2011). This again indicates that individuals who have weak top down control over feeding are likely to be influenced to overeat in the presence of food cues. Although this thesis did not set out to explore the role of impulsivity in FPB, a number of experiments did include the BIS measure (Carver and White, 1994). Low scores on these measures are thought to represent individuals with a diminished ability to suppress behaviour associated with negative consequences (Davies, Strachan and Berkson, 2004). Experiment 1 found that all three of the PFS scales correlated with the BIS measure, which indicates that individuals who finding it difficult to suppress their behaviour are also more sensitive to the pull of food cues in the environment. Future experimental work developed from this thesis will need to consider the role of decision making and impulsivity in more depth.

6.1.4. How does the processing of reward contribute to attentional bias and craving?

The final chapter of this thesis aimed to understand how the incentive value of cues impact on FPB. It can be argued that the novel methodology used in this chapter address some of the identified limitations of the current FPB literature. This methodology does not fully address the impact that food preference, learning history or ambivalence has on task performance. The training task developed from Brunstrom et al. (2009, 2010) was successful at manipulating preference for novel stimuli. Participants generally increased their reported liking for the CS which had been paired with the highest reward contingency and decreased their liking for symbols which had not been paired with reward (Experiments 4, 5 and 6). Although these effects were small they were found after only a small period of training (around ten minutes). It can be proposed that stronger effects would be found if the period of training was increased or if participants were trained until contingency awareness was established.

The results presented in this chapter indicate that training allows the CS+ to become a cue for reward expectancy. In line with theoretical account of attentional bias (e.g. Field and Cox, 2008) enhanced attentional processing was allocated to these cues in attentional tasks (Experiments 4 and 5) whilst the presence of the CS+ had the potential to generate craving for hedonic foods (Experiment 6) . It is unclear why for both experiments 4 and 5 the more salient CS+ appear to be those paired with low and high reward contingencies. On reflection it is unclear whether this finding indicates that reward coding develops independently of valence or whether the effects are a consequence of devaluation. This needs to be explored in more depth by future research; it would be particularly interesting to establish the impact of explicitly devaluing the CS+. A future extension of the experiments in Chapter 5 would seek to take a baseline measure of attentional bias following training; participants would then be asked to consume the US until satiety. This experiment would allow assessment of whether cues would still grab attention when they were devalued. It needs to be establish what happens when the CS+ are no longer biologically relevant; one suggestion is that they would no longer be salient targets on an attentional task such as the AB. However it could equally be proposed that the CS+ would remain salient for an individual who's hyper-responsivity to food cues puts them at risk of weight gain. Therefore this work needs to be extended using obese and normal weight participants.

6.1.5 Does attentional biases reflect enhanced orientation or delayed disengagement to food stimuli?

The studies presented in this thesis did not fully establish whether FPB was an expression of sustained attention or quicker orientation to food cues. Experiment 2 found evidence that FPB was caused by quicker orientation to food cues. In contrast Chapter 5 used the AB task to measure attention. The index of attentional bias gained from this measure is considered to indicate quicker orientation of attention (Field and Eastwood, 2005). Both AB experiments showed that salient targets embedded in the RSVP stream were able to grab greater attention. In Experiment 4 targets which had previously been associated with food information were most likely to "survive" the attentional blink. While Experiment 5 suggests that participants were quicker at identifying food related targets (T1) which allowed them to more accurately report the content of T2. Any disparity between findings from chapters 4 and 5 could be because the VDP and AB paradigms measure two different constructs of attention. The AB task measures the early processes related to attention and working memory, where as the VDP task measures RT to food stimuli.

6.2 Limitations

A number of limitations must be considered when interpreting the thesis findings. Specific limitations have been discussed in relevant empirical chapters however the more general limitations of the thesis also need to be discussed.

6.2.1 Representation

Demographic characteristics of all experimental groups indicate a trend towards the majority of participants being non obese and females. Additionally the sample population were recruited from a University in South Wales, UK therefore the majority of participants were young adults, educated to degree level or higher and Caucasian. Therefore the extent to which results and conclusions drawn from this thesis can be directly generalised to wider ethnic groups, older adults or clinically obese populations is limited. It may be predicted that if these experiments were conducted in a clinical population (e.g. individuals who were seeking surgical treatment for weight loss) results may not be directly comparable to this non clinical sample.

6.2.2. Scope

It was beyond the reach of this thesis to provide measures of all eating behaviours which may be implicated in the control of eating. One factor which was not accounted for in this thesis was the role of impulsivity. Although Experiments 1 and 2 did include the BIS measure (this provides an index of individual ability to inhibit behaviour which has negative consequences) this measure was not used throughout the course of the thesis. Over the course of developing this body of work, impulsivity has gained increased attention in both the addiction and FPB literature. Future work would aim to build upon how these measures of impulsivity are likely to influence FPB and overeating. It would also be interesting to establish how impulsivity relates to the behavioural and ERP findings of this thesis (see recommendations for future work section 6.3).

6.2.3 Methodological issues

There are a number of general methodological issues which may limit the conclusions made here. Experiments 2, 3, 4, 5 and 6 all took place in a laboratory environment. The artificial bases of experimental measures such as the AB and VDP tasks are unlikely to directly mimic how food cues are attended to in the real world. Therefore care must be taken when extrapolating findings to wider contexts. One way that this may be overcome in future research is by using eye tracking to measure gaze during shopping. This would allow research to explore if cues affect real world food choices.

Experiment 3 measured the intake of two palatable foods, although care was taken to reduce any influence that the researcher had on intake behaviour (researcher did not stay in the room during the taste task, task took place in a kitchen environment) it is difficult to establish if participants consumed similar amounts of the snack foods as they would have in a naturalistic setting.

There are also a number of limitations to the electrophysiological data collected in this study. The ERP analysis was based on a small sample of participants. Similarly only participants that had than 10 valid trials recorded for each condition were included in the data analysis. Trials were removed if artefacts indicated participant movement or were unduly affected by eye movements/eye blinks. In retrospect the task used in Chapter 5 could be improved by increasing the number of trials, this would have hopefully escalated the number of valid trials recorded for each participant. Higher ERP averages would have further reduced the EEG noise through signal averaging and this may have made the ERP data easier to interpret.

6.2.4 Data analyses

Some of the data collected in this thesis were non-normal and thus violated the assumptions of parametric tests. Although non parametric tests were applied to this data it was not possible to assess interactions between factors using these approaches. Therefore the ANOVA procedure was used to investigate interactions between variables despite the assumption of normality not being met. This should be taken into consideration when interpreting this thesis data.

6.3 Clinical Applications

The findings from this thesis along with the results from the wider literature indicate that the existence of a phenotype of cue reactivity, this is likely to be a hallmark of obesity risk. Cue reactive individuals are susceptible to weight gain due to a hypersensitivity to food cues. The modern food environment can be considered to promote obesity through the ubiquitous presence of food cues. Therefore a greater understanding of the mechanism involved in attentional bias may help target the design of food environments which do not promote obesity.

Interventions can be developed using the techniques outlined in Chapter 4. In the addiction literature attentional retraining has been successfully used in clinical settings: Schoenmakers et al. (2010) used attentional retraining to reduce attentional bias in individual receiving treatment for alcohol dependence. Participants who completed the intervention were discharged from the treatment centre one month earlier than those who completed the control training. Comparable to the addiction literature attentional retraining could also be used in the treatment of obesity. It is doubtful that attentional retraining would have any long lasting effects on attentional capture. However the paradigm could be used as a educational tool to demonstrate how paying enhanced attention to food cues in the environment impacts on food choice and eating behaviour.

The concept of their being a phenotype of cue reactivity may also be useful to obesity treatment. The work in this thesis could be used to develop a diagnostic tool which allows health professional to identify individuals who are most at risk of overeating when food cues are present. Specific interventions could be designed which target cue reactive populations. This is a group which may be particularly vulnerable to unsuccessful dieting (as dietary restraint is associated with increased attentional bias to food cues). In cue reactive populations weight loss interventions may have more successful outcomes if they focus on producing awareness of the power that food cues have on behaviour. This would allow individuals to exert more vigilant top down control over their eating behaviour when they are in obesogenic environments.

Cue reactive eating is often driven by automaticity. This is that decisions about food choice/intake are driven more by the presence of food cues in the environment than conscious decisions about intake. The training paradigm used in Chapter 6 can be modified to explore the role of automaticity in food choice. Participants could be trained to associated neutral cues with thoughts about their own weight loss goals. Subsequently these neutral cues could be used to prime dieting goals during times of temptation.

6.4 Future research

This thesis has highlighted a number of directions for future research. Future research in this area should aim to establish if the findings from this thesis are applicable to a clinically obese sample. This would strength the argument that the obese overeat as a result of hypersensitivity to food cues.

It also appears important to clarify whether FPB is based on initial orientation of attention or delayed disengagement as this is still a contentious issue within the literature. It would therefore be useful to extend the VDP experiments from Chapter 2 by including an additional measure of eye gaze. Work by Wetherman et al. 2011; has shown quicker at orienting attention to food cues on the VDP . However neither of these study successfully demonstrated that indices of FPB increase with quicker detection. This will allow further clarification of whether the evidence of delayed disengagement for stimuli at 100ms is valid. But also establish whether FPB is indeed caused by quicker orientation to food stimuli.

Research also needs to focus on substantiating the proposed link between FPB and overeating. What is essentially a central prediction of the FPB literature still remains inadequately justified by empirical data. For example Experiment 3 could be extended by using a more varied measure of ad libitum intake. It was suggested in the discussion of Experiment 3 that a preferable protocol would be to use a disguised taste task that measured participant's food choices and subsequent intake from a buffet of sweet and savoury foods. This study would also benefit from including a control group which did not complete any attentional retraining. It would also be of interest to explore if attentional retraining had any beneficial effects on individuals who were undergoing clinical treatment for weight loss.

Chapter 5 did not establish whether the conditioning procedure was able to successfully manipulate calorie intake. This could be measured experimentally by having participants complete a disguised taste task following training. Intake could be manipulated by incorporating a CS+ prime; this could be done by presenting food items on plates which had the different CS symbols printed on them. A more subtle method would be to place a poster containing the CS+ symbol in the room where the taste task was being carried out. It would be interesting to establish if this procedure would elicit changes in calorie intake that directly correspond to the reward contingency of the prime. This would strengthen the argument towards cue priming being an automatic process. Finally as recommended in the discussion of Chapter 5 it appears sensible to establish whether extending the training paradigm used in Experiments 4, 5 and 6 will enhance the effects of conditioning. To address this issue it would be useful to train participants over a 3 day period or until they were able to explicitly demonstrate that they were aware of the reward contingencies paired with each symbol. The electrophysiological data from this chapter could be further improved by increasing the sample size and using a within subjects approach.

Finally the consequences of obesity make it increasingly difficult to interpret attentional bias data; the data collected in this thesis suggests that future work into food processing bias should focus on recruiting populations who are at risk of obesity but who's BMI is still within the normal weight range. Longitudinal research using this type of sample would allow examination of how attention processes alter behaviour (e.g. increased craving, greater sensitivity to food cues in shopping environment) and the consequences that these have on food intake.

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Appendices

Appendix A

Three Factor Eating Questionnaire

Please answer each question by *circling* the appropriate response.

1.	When I smell a pizza or see a pizza straight from the oven, I find it difficult to keep from eating, even if I have just finished a meal.	**True/False**
2.	I usually eat too much as social occasions, like parties and BBQs.	**True/False**
3.	When I have eaten my quota of calories I am usually good about not eating any more.	**True/False**
4.	I deliberately take small helpings as a means of controlling my weight.	**True/False**
5.	Sometimes things just taste so good that I keep eating even when I am no longer hungry.	**True/False**
6.	When I feel anxious I find myself eating.	**True/False**
7.	Life is too short to worry about dieting.	**True/False**
8.	Since my weight goes up and down I have gone on diets more than once.	**True/False**
9.	When I am with someone who is overeating I usually overeat too.	**True/False**
10.	I have a pretty good idea of the number of calories in common food.	**True/False**
11.	Sometimes when I start eating I just can't seem to stop.	**True/False**
12.	It is not difficult for me to leave something on my plate.	**True/False**
13.	While on a diet if I eat food that is not allowed I consciously eat less for a period of time to make up for it.	**True/False**
14.	When I feel blue I often over eat.	**True/False**
15.	I enjoy eating too much to spoil it by counting calories or watching my weight.	**True/False**
16.	I often stop eating when I am not really full as a conscious means of limiting the amount I eat.	**True/False**
17.	My weight has hardly changed at all in the last ten years.	**True/False**
18.	When I feel lonely I console myself by eating.	**True/False**
19.	I consciously hold back at meals in order not to gain weight.	**True/False**
20.	I eat anything I want any time I want.	**True/False**
21.	Without even thinking about it I take a long time to eat.	**True/False**
22.	I count calories as a conscious means of controlling my weight.	**True/False**
23.	I do not eat some foods because they make me fat.	**True/False**
24.	I pay a great deal of attention to changes in my figure.	**True/False**
25.	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**

Please answer the following questions by *circling* the number above the response that is appropriate to you. Choose only one response per item. Di not leave any blank.

26. How often are you dieting in a conscious effort to control your weight?

1	2	3	4
rarely	**sometimes**	**usually**	**always**

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

1	2	3	4
not at all	**slightly**	**moderately**	**very much**

28. Do your feelings of guilt about overeating help you to control your food intake?

1	2	3	4
never	**rarely**	**often**	**always**

29. How conscious are you of what you are eating?

1	2	3	4
not at all	**slightly**	**moderately**	**extremely**

30. How frequently do you avoid stocking up on tempting foods?

1	2	3	4
almost never	**seldom**	**usually**	**almost always**

31. How likely are you to shop for low calorie foods?

1	2	3	4
unlikely	**slightly unlikely**	**moderately likely**	**very likely**

32. Do you eat sensibly in from of others and splurge alone?

1	2	3	4
never	**rarely**	**often**	**always**

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

1	2	3	4
unlikely	**slightly likely**	**moderately likely**	**very likely**

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

1	2	3	4
unlikely	**slightly likely**	**moderately likely**	**very likely**

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

1	2	3	4
never	**rarely**	**sometimes**	**at least once a week**

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

0 = eat whatever you want, whenever you want it
1 = usually eat whatever you want, whenever you want it
2 = often eat whatever you want whenever you want it

3 = often limit food intake, but often give in
4 = usually limit food intake and rarely give in
5 = constantly limiting food intake, never giving in

37. To what extent does this statement describe your eating behaviour?

"I start dieting in the morning, but because of any number of things that happen during the day, by the evening I have given up and eat what I want, promising myself to start dieting again tomorrow."

1	2	3	4
not like me	**a little like me**	**pretty good description of me**	**describes me perfectly**

Appendix B

Dutch Eating Behaviour Questionnaire

Please answer the following questions by *circling* the response that is most appropriate to you. Choose only one response for each item, do not leave any blank.

1 •Do you have the desire to eat when you are irritated?

Never Seldom Sometimes Often Very often

2 •Do you have a desire to eat when you have nothing to do?

Never Seldom Sometimes Often Very often

3 •Do you have a desire to eat when you are depressed or discouraged?

Never Seldom Sometimes Often Very often

4 •Do you have a desire to eat when you are feeling lonely?

Never Seldom Sometimes Often Very often

5 •Do you have a desire to eat when somebody lets you down?

Never Seldom Sometimes Often Very often

6 •Do you have a desire to eat when you are cross?

Never Seldom Sometimes Often Very often

7 •Do you have a desire to eat when you are approaching something unpleasant to happen?

Never Seldom Sometimes Often Very often

8 •Do you get the desire to eat when you are anxious, tense or worried?

Never Seldom Sometimes Often Very often

9 •Do you have a desire to eat when things are going against you or when things have gone wrong?

Never Seldom Sometimes Often Very often

10 •Do you have a desire to eat when you are frightened?

Never Seldom Sometimes Often Very often

11 •Do you have a desire to eat when you are disappointed?

Never Seldom Sometimes Often Very often

12 •Do you have a desire to eat when you are emotionally upset?

Never Seldom Sometimes Often Very often

13 •Do you have a desire to eat when you are bored or restless?

Never Seldom Sometimes Often Very often

Appendix C

BIS/BAS

For each item, indicate how much you agree or disagree with what the item says. Please respond to all items; do not leave any blank. Choose only one response to each statement.

Even if something bad is about to happen to me, I rarely experience fear or nervousness.

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

When I'm doing well at something I love to keep at it.

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

When I get something I want, I feel excited and energized.

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

Criticism and scolding hurts me quite a bit.

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

I feel pretty worried and upset when I think or know somebody is angry at me.

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

When I see an opportunity for something I like I get excited right away.

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

If I think something unpleasant is going to happen I usually get pretty "worked up".

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

When good things happen to me. it affects me strongly.

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

I feel worried when I think I have done poorly at something important.

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

I have very few fears compared to my friends.

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

It would excite me if to win a contest.

1	2	3	4
ab **very true for me**	**somewhat true for me**	**somewhat false for me**	**very false for me**

I worry about making mistakes.

1	2	3	4
very true for me	**somewhat true for me**	**somewhat false for me**	**very false for me**

Appendix D

Power of Food Scale

Please indicate the extent to which you agree that the following items describe you.

I find myself thinking about food even when I'm not physically hungry.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

When I'm in a situation where delicious foods are present but I have to wait to eat them, it is very difficult for me to wait.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

I get more pleasure from eating than I do from almost anything else.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

I feel that food is to me like liquor is to an alcoholic.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

If I see or smell a food I like, I get a powerful urge to have some.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

When I'm around a fattening food I love, it's hard to stop myself from at least tasting it.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

I often think about what foods I might eat later in the day.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

It's scary to think of the power that food has over me.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

When I taste a favourite food, I feel intense pleasure.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

When I know a delicious food is available, I can't help myself from thinking about having some.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

I love the taste of certain foods so much that I can't avoid eating them even if they're bad for me.

	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

When I see delicious foods in advertisements or commercials, it makes me want to eat.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

I feel like food controls me rather than the other way around.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

Just before I taste a favourite food, I feel intense anticipation.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

When I eat delicious food I focus a lot on how good it tastes.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

Sometimes, when I'm doing everyday activities. I get an urge to eat "out of the blue" (for no apparent reason).

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

I think I enjoy eating a lot more than most other people.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

Hearing someone describe a great meal makes me really want to have something to eat.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

It seems like I have food on my mind a lot.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

It's very important to me that the foods I eat are as delicious as possible.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

Before I eat a favourite food my mouth tends to flood with saliva.

1	2	3	4	5
Don't agree At all	**Agree a little**	**Agree somewhat**	**Agree**	**Strongly agree**

Appendix E

Food Craving Questionnaire

How much do you agree with each of these statements right now, at this very moment

1. Food cravings invariable make me think of ways to get what I want to eat

1	2	3	4
Strongly Disagree	Neutral	Agree	Strongly Agree

2. Whenever I have craving I find myself making plans to eat

1	2	3	4
Strongly Disagree	Neutral	Agree	Strongly Agree

3. When I crave certain foods I usually try to eat them as soon as I can

1	2	3	4
Strongly Disagree	Neutral	Agree	Strongly Agree

4. I eat to feel better

1	2	3	4
Strongly Disagree	Neutral	Agree	Strongly Agree

5. Sometimes eating makes things seem just perfect

1	2	3	4
Strongly Disagree	Neutral	Agree	Strongly Agree

6. Eating what I crave makes me feel better

1	2	3	4
Strongly Disagree	Neutral	Agree	Strongly Agree

7. When I eat what I crave I feel great

1	2	3	4
Strongly Disagree	Neutral	Agree	Strongly Agree

8. When I eat food I feel comforted

1	2	3	4
Strongly Disagree	Neutral	Agree	Strongly Agree

9. When I satisfy a craving I feel less depressed

1	2	3	4
Strongly Disagree	Neutral	Agree	Strongly Agree

10. Eating calms me down

1	2	3	4
Strongly Disagree	Neutral	Agree	Strongly Agree

11. I feel less anxious after I eat

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

12. When I crave something I know I won't be able to stop eating once i start

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

13. If I eat what I am craving I often lose control and eat too much

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

14. If I get what I am craving I cannot stop myself from eating it

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

15. I have no will power to resist my food crave

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

16. Once I start eating I have trouble stopping

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

17. If I give in to a food craving all control is lost

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

18. I feel like I have food on my mind all of the time

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

19. I find myself preoccupied with food

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

20. I can't stop thinking about eating no matter how hard I try

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

21. I spend a lot of time thinking about whatever it is I will eat next

1	2	3	4

Strongly Disagree **Neutral** **Agree** **Strongly Agree**

22. I daydream about food

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

23. Whenever I have a food craving I keep on thinking about eating until I actually eat the food

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

24. If I am craving something, thoughts of eating just consume me

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

25. Thinking about my favorite foods make my mouth water

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

26. I crave foods when my stomach is empty

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

27. If feel as if my body asks me for certain foods

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

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

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

29. I crave foods when I feel bored , angry or sad

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

30. When I m stressed out I crave food

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

31. My emotions often make me want to eat

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

32. I crave foods when I'm upset

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

33. Being with someone who is eating often makes me hungry

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

34. Whenever I go to a buffet I end up eating more than what I needed

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

35. It is hard for me to resist the temptation to eat appetizing foods that are in my reach

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

36. When I am with someone who is overeating I usually over eat too

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

37. I hate it when I give into craving

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

38. I often feel guiltily for craving certain foods

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

39. When I eat what I am craving I feel guilty about myself.

1	2	3	4
Strongly Disagree	**Neutral**	**Agree**	**Strongly Agree**

Appendix F

Experiment 2 consent form

Mood, Food and Cognition Performance

Hello and welcome to my experiment!
This study is designed to investigate the relationship between mood, eating behaviour and cognition.
During the next 45 minutes you will be asked to complete :

- Set of visual analogue scales to take a baseline measure of mood and appetite.
- A computer based task that measures your cognitive performance.
- A set of general questionnaires about your eating habits.
- Rate a number of pictures for desirability and familiarity.
- Measurement of your height and weight

Any information that you provide will be kept private and confidential and will be anonymised. You have the right to withdraw from the experiment at any time. You will receive 3 subject pool credits for completing this study.

Participant consent:
Please read the following statements and circle your response to each one:

- I have read and understood the above information about the study **YES/NO**
- I understand that I am not obliged to take part in the study and that I can withdraw at any time **YES/NO**
- I understand that any information I give will be treated confidentially **YES/NO**
- I do not have any food allergies **YES/NO**
- I have not been diagnosed with diabetes **YES/NO**
- I have not been diagnosed with epilepsy **YES/NO**
- I am not vegetarian/ vegan **YES/NO**
- I am not currently dieting **YES/NO**
- I agree to participate in the study **YES/NO**

Signed.................................... Date:.................................

Age...........................

Gender........................

Student ID.....................

Height ....

Weight ....

The heaviest weight that you have ever been ....

Experiment 3 consent form

The role of mood in cognitive performance

Hello and welcome to my experiment!

This study is designed to investigate the relationship between mood, eating behaviour and cognition. During the next 70 minutes you will be asked to complete :

- Set of visual analogue scales to take a baseline measure of mood and appetite.
- A number of computer based tasks that measures your cognitive performance.
- A set of general questionnaires about your eating habits.
- Taste and rate two food items as part of a separate experiment into taste preference
- Measurement of your height and weight

Any information that you provide will be kept private and confidential and will be anonymised. You have the right to withdraw from the experiment at any time. You will receive 4 subject pool credits for completing this study.

Participant consent:

Please read the following statements and circle your response to each one:

- I have read and understood the above information about the study **YES/NO**
- I understand that I am not obliged to take part in the study and that I can withdraw at any time **YES/NO**
- I understand that any information I give will be treated confidentially **YES/NO**
- I do not have any food allergies **YES/NO**
- I have not been diagnosed with diabetes **YES/NO**
- I have not been diagnosed with epilepsy **YES/NO**
- I am not vegetarian/ vegan **YES/NO**
- I am not currently dieting **YES/NO**
- I agree to participate in the study **YES/NO**

Signed.................................... Date:.................................

Age...........................

Gender.......................

Student ID.....................

Height ....

Weight ....

The heaviest weight that you have ever been ....

Experiment 4 and 5 consent form

<u>EEG study investigating in the influence of chocolate deprivation on mood and cognitive performance.</u>

We are interested in the effects of depriving people of chocolate for 48 hours on mood, how much chocolate is liked, and sensory ratings of the taste of chocolate. In addition, patterns of electrical activity in the brain will be recorded using electroencephalography (EEG recording) techniques during completion of a rapid serial visual presentation task (RSVP task).
Following completion of a screening questionnaire you will be assigned to one of two groups. One group of volunteers will be asked to refrain from consuming chocolate for 2 days prior to attending the lab whilst the other half will be asked to stick to their usual eating habits. All volunteers will be asked to keep a record of their mood during this 2 day period.
On the day of the study you will need to report to the EEG Lab (room 705 Vivian tower) at a set time. Prior to coming to the lab please eat your usual breakfast and morning drinks at the usual time. On arrival in the lab you will be asked to report your current mood using a simple paper and pencil task. You will then be asked to taste and rate a small sample of chocolate. Once this has been done the researcher will take you through the EEG procedure, which requires us to attach some sensors onto a cap and put a bit of conductive gel beneath them on your scalp. Once the EEG set up has been completed you will be asked to say how much you like a number of black and white symbols. After you have rated the patterns you will take part in a computer game where your task is to find a red rectangle hiding behind symbols on the computer screen. Finding a red rectangle will be rewarded with a piece of chocolate. After a short break you will do rapid serial visual presentation task where you will be asked to spot and report digits and target symbols. Once this task is completed you will report your mood again and re-do the ratings of the geometric patterns. Finally the researcher will remove the recording sensors from your scalp and reimburse you for your assistance. You will be paid £20 for your participation.

As part of the study you will be required to consume some chocolate chips (containing dairy products, soya products and which have been prepared in a factory where nuts are handled). A complete list of ingredients is available on request.
Participant consent:
Please read the following statements and circle your response to each one:

- I have read and understood the above information about the study **YES/NO**
- I understand that I am not obliged to take part in the study and that I may withdraw at any time without penalty **YES/NO**
- I understand that any information I give will be treated confidentially **YES/NO**
- I **DO/DO NOT** have any food allergies or intolerances
- I **AM/AM NOT** currently taking any medication
- I **DO/DO NOT** have diabetes
- I agree to participate in the study **YES/NO**

Signed: .... Name: .... Date:...............

Experiment 6 consent form

<u>Study investigating the influence of chocolate on ratings of mood and cognitive performance</u>

We are interested in the effects of chocolate on mood, how much chocolate is liked and the sensory ratings of the taste of chocolate.
During today's testing session you will be asked to report you current mood using a simple pen and paper task. You will then be asked to taste and rate a small sample of chocolate. You will be asked to say how much you like a number of black and white symbols. After you have rated these patterns you will take part in a computer game where your task is to find a red rectangle hiding behind a symbol on the computer screen. Finding a red rectangle will be reward with a piece of chocolate. After a short break you then be asked to rate how much you would like to consume a number of food and drink images.
As part of the study you will be required to consume smarties (contain dairy products and have been prepared in a factory where nuts are handled). A complete list of ingredients are available on request. If you are having EEG recorded during this testing session, the research will take you through the EEG procedure, which requires us to attach some sensors onto a cap and put a bit of conductive gel beneath them on your scalp. The researcher will remove the recording sensors from your scalp at the end of the testing session and reimburse you for your assistance. You will be paid £20 for your participation.

Participant consent:
Please read the following statements and circle your response to each one:

- I have read and understood the above information about the study **YES/NO**
- I understand that I am not obliged to take part in the study and that I may withdraw at any time without penalty **YES/NO**
- I understand that any information I give will be treated confidentially **YES/NO**
- I **DO/DO NOT** have any food allergies or intolerances
- I **AM/AM NOT** currently taking any medication
- I **DO/DO NOT** have diabetes
- I agree to participate in the study **YES/NO**

Signed: .... Name: .... Date:...............

Appendix G

Mood Questionnaire [Experiments 2,3,4,5 and 6]

Please place a mark through each of the following lines indicating how you are feeling at the moment.
For example:

How tired do you feel?

not at all ______________________________________|__________ extremely

How hungry do you feel?

not at all ____ extremely

How thirsty do you feel?

not at all ____ extremely

How clear-headed do you feel?

not at all ____ extremely

How happy do you feel?

not at all ____ extremely

How full do you feel?

not at all ____ extremely

How friendly do you feel?

not at all ____ extremely

How jittery do you feel?

not at all ____ extremely

How energetic do you feel?

not at all ____ extremely

How nauseous do you feel?

not at all ____ extremely

How relaxed do you feel?

not at all ____
extremely

Appendix G

General Mood Questionnaire, Chocolate Deprivation Group [Experiments 4 and 5]

Please place a line through each of the following lines indicating how you are feeling at the moment. For example

How happy do you feel?

not at all ________|_______________________________ extremely

Time 1: After evening meal (around 7pm)

How hungry do you feel?

not at all ____
extremely

How much are you are missing eating chocolate?

not at all ____
extremely

How much are thinking about chocolate?

not at all ____
extremely

How difficult is it to resist eating chocolate?

not at all ____
extremely

Time 2: Before bed (about 11pm)

How hungry do you feel?

not at all ____
extremely

How much are you missing eating chocolate?

not at all ____
extremely

How much are you thinking about chocolate?

not at all ______________________________ extremely

How difficult is it to resist eating chocolate?

not at all ______________________________ extremely

Time 3: After breakfast (around 10am)

How hungry do you feel?

not at all ______________________________ extremely

How much are you missing eating chocolate?

not at all ______________________________ extremely

How much are you thinking about chocolate?

not at all ______________________________ extremely

How difficult is it to resist eating chocolate?

not at all ______________________________ extremely

Time 4: After lunch (around 2pm)

How hungry do you feel?

not at all ______________________________ extremely

How much are you missing eating chocolate?

not at all ______________________________ extremely

How much are you thinking about chocolate?

not at all ______________________________ extremely

How difficult is it to resist eating chocolate?

not at all ______________________________ extremely

Time 5: After evening meal (around 7pm)

How hungry do you feel?

not at all ______________________________ extremely

How much are you are missing eating chocolate?

not at all ______________________________ extremely

How much are thinking about chocolate?

not at all ______________________________ extremely

How difficult is it to resist eating chocolate?

not at all ______________________________ extremely

Time 6: Before bed (about 11pm)

How hungry do you feel?

not at all ______________________________ extremely

How much are you missing eating chocolate?

not at all ______________________________ extremely

How much are you thinking about chocolate?

not at all ______________________________ extremely

How difficult is it to resist eating chocolate?

not at all ______________________________ extremely

Time 7: After breakfast (around 10am)

How hungry do you feel?

not at all ______________________________ extremely

How much are you missing eating chocolate?

not at all
extremely

How much are you thinking about chocolate?

not at all
extremely

How difficult is it to resist eating chocolate?

not at all
extremely

Time 8: After lunch (around 2pm)

How hungry do you feel?

not at all
extremely

How much are you missing eating chocolate?

not at all
extremely

How much are you thinking about chocolate?

not at all
extremely

How difficult is it to resist eating chocolate?

not at all
extremely

General Mood Questionnaire, Non Chocolate Deprived group (Experiments 4 and 5)

Please place a line through each of the following lines indicating how you are feeling at the moment.
For example

How happy do you feel?

not at all ——————|—————————————————— extremely

Time 1: After evening meal (around 7pm)

How hungry do you feel?

not at all ____ extremely

How relaxed do you feel?

not at all ____ extremely

How friendly do you feel?

not at all ____ extremely

How clear-headed do you feel?

not at all ____ extremely

Time 2: Before bed (about 11pm)

How hungry do you feel?

not at all ____ extremely

How relaxed do you feel?

not at all ____ extremely

How friendly do you feel?

not at all ____ extremely

How clear-headed do you feel?

not at all ____ extremely

Time 3: After breakfast (around 10am)

How hungry do you feel?

not at all ______________________________ extremely

How relaxed do you feel?

not at all ______________________________ extremely

How friendly do you feel?

not at all ______________________________ extremely

How clear-headed do you feel?

not at all ______________________________ extremely

Time 4: After lunch (around 2pm)

How hungry do you feel?

not at all ______________________________ extremely

How relaxed do you feel?

not at all ______________________________ extremely

How friendly do you feel?

not at all ______________________________ extremely

How clear-headed do you feel?

not at all ______________________________ extremely

Time 5: After evening meal (around 7pm)

How hungry do you feel?

not at all ____ extremely

How relaxed do you feel?

not at all ____ extremely

How friendly do you feel?

not at all ____ extremely

How clear-headed do you feel?

not at all ____ extremely

Time 6: Before bed (about 11pm)

How hungry do you feel?

not at all ____ extremely

How relaxed do you feel?

not at all ____ extremely

How friendly do you feel?

not at all ____ extremely

How clear-headed do you feel?

not at all ____ extremely

Time 7 After breakfast (around 10am)

How hungry do you feel?

not at all ______________________________ extremely

How relaxed do you feel?

not at all ______________________________ extremely

How friendly do you feel?

not at all ______________________________ extremely

How clear-headed do you feel?

not at all ______________________________ extremely

Time 8: After lunch (around 2pm)

How hungry do you feel?

not at all ______________________________ extremely

How relaxed do you feel?

not at all ______________________________ extremely

How friendly do you feel?

not at all ______________________________ extremely

How clear-headed do you feel?

not at all ______________________________ extremely

Appendix H

VAS scales for rating food pleasantness [Experiments 2,3,4,5 and 6]

Participant number: **Date:**

Answer each question

How creamy is the chocolate?

not at all ____
extremely creamy
creamy

How sweet is the chocolate?

not at all ____
extremely sweet
sweet

How rich is the chocolate?

not at all ____
extremely rich
rich

How pleasant is the chocolate?

not at all ____
extremely pleasant
pleasant

How strong is your desire to eat more of the chocolate?

not at all ____
extremely strong
strong

Appendix I

Stimuli Evaluation Scale (Experiment 2)

Name/ID Number: **Date:**

Please take a 2-3 minutes to think about the image in front of you, concentrate on what thoughts the image invokes. How do the colours make you feel.

Please place a line through each of the following lines indicating how you are feeling at the moment.

How vibrant is the image?

not at all ______________________________ extremely

How engaging is the image?

not at all ______________________________ extremely

How rich in detail is the image?

not at all ______________________________ extremely

How pleasant is the image?

not at all ______________________________ extremely

How intense are the colours in the image?

not at all ______________________________ extremely

Appendix J

Awareness Assessment (Experiments 4, 5 and 6)

The pattern used during the 'find the red rectangle task' is displayed on the computer screen in front of you.

1. Can you guess the purpose of the 'red rectangle task'?

2. In relation to the pattern you chose the most often, explain why you liked this pattern.

3. In the counting task phase of the red rectangle task were you more likely to be asked to eat a chocolate chip after you saw a particular pattern?

   Yes No Don't know

   If yes, which pattern (on computer screen) 1 2 3 4 5 6?

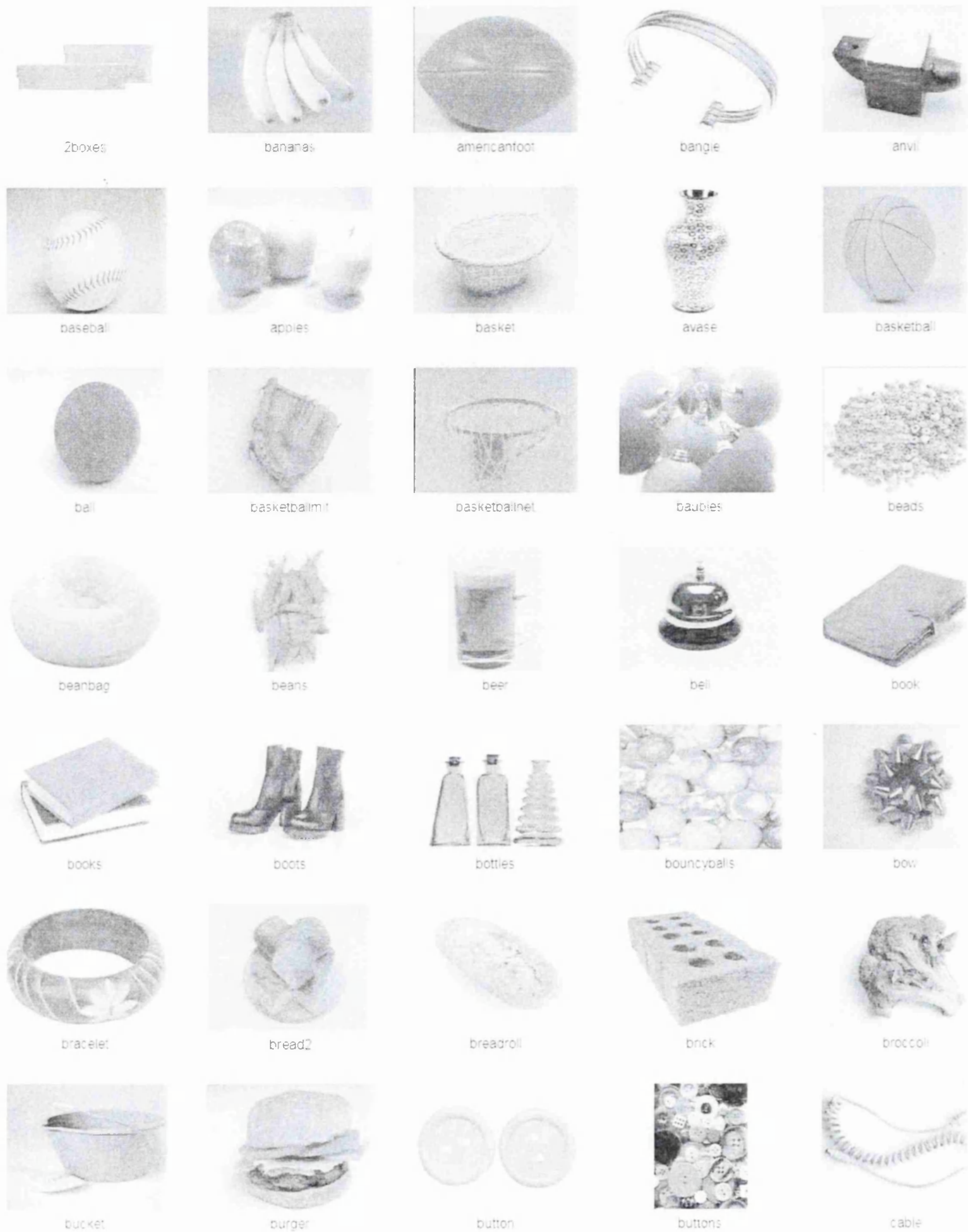
4. In the counting task phase of the red rectangle task were you more likely to be asked to see a particular pattern when you found a red rectangle?

   Yes No Don't know

   If yes, which pattern (on computer screen) 1 2 3 4 5 6?

Appendix K *Stimuli Set for VDP[Experiments 2 and 3]*

Stimuli Set - Experiment 2

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candle

car1

carrots

cat

cat2

cauli

cd

cdplayer

cheesegrater

cherries

chessboard

chococake2

clamp

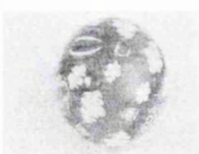
clearpots

clip

clock

coffee

coins

cola2

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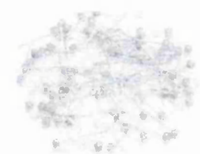
colouredcandles

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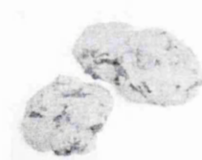
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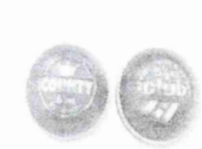
cookies1

cotton

cottonwool

couscous

crackers

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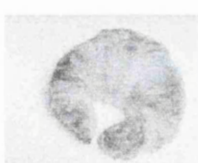
crispbread

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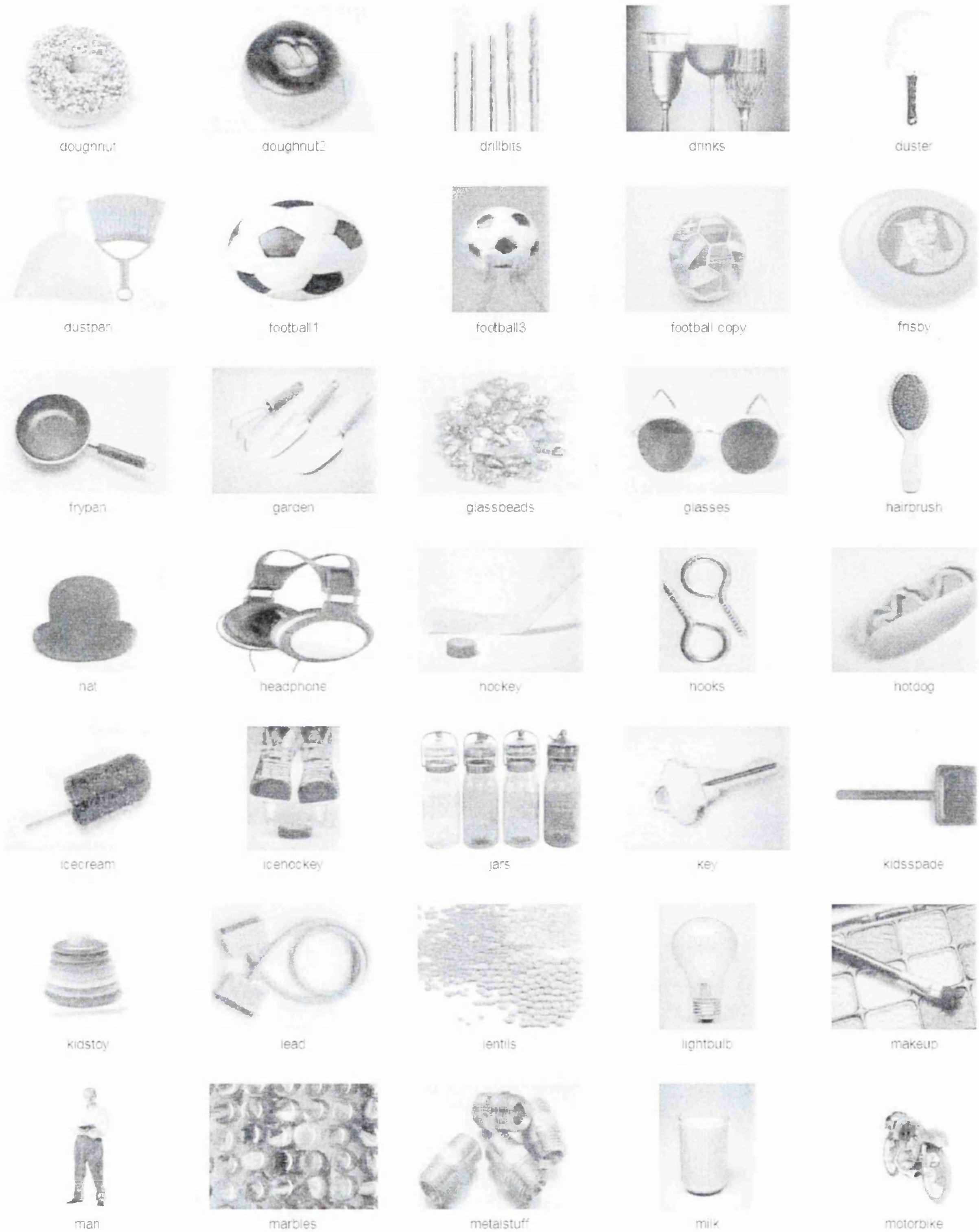
dog

dog2

dog3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drinks
duster
dustpan
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football3
football copy
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hat
headphone
hockey
hooks
hotdog
icecream
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metalstuff
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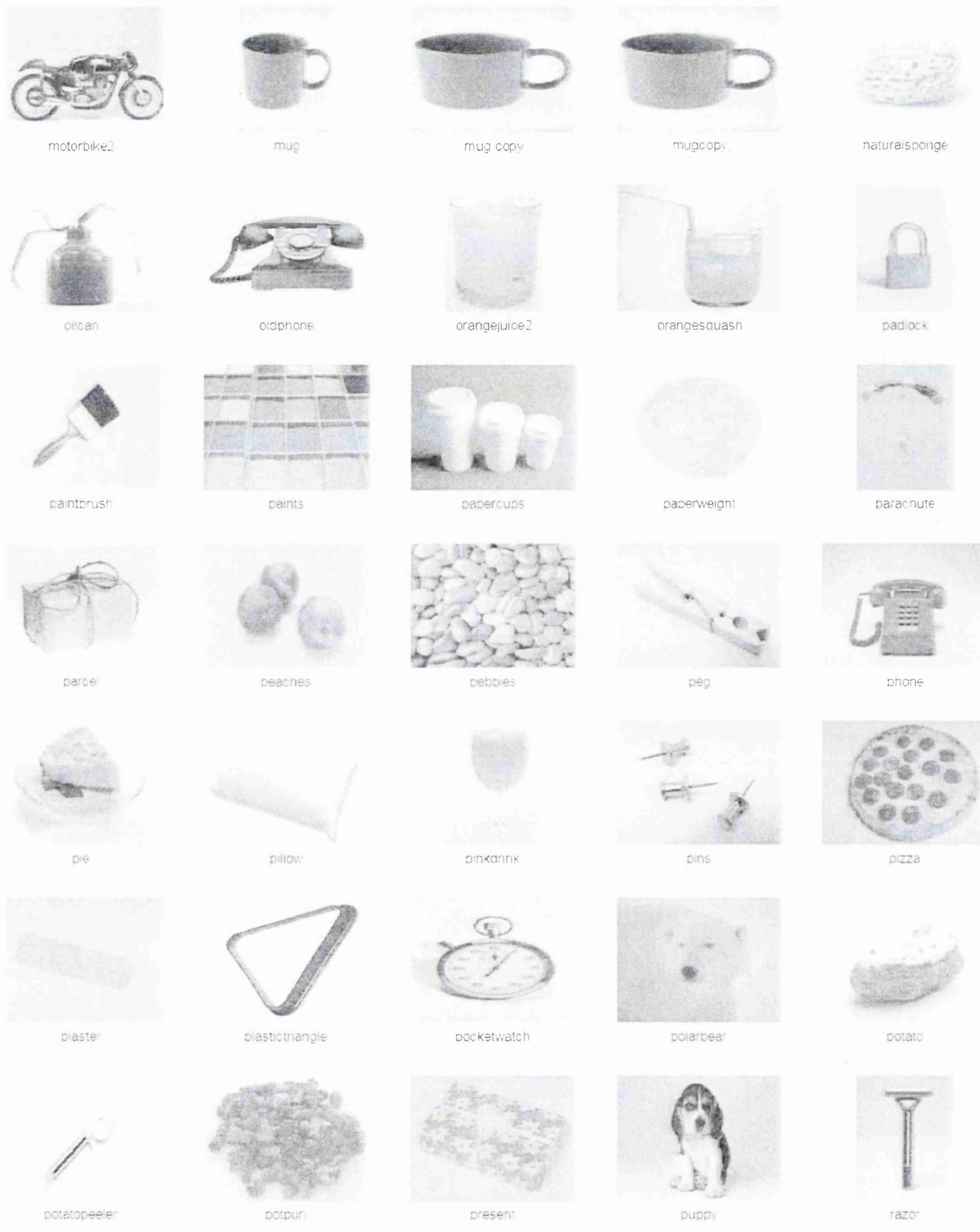
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oldphone
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papercups
paperweight
parachute
parcel
peaches
pebbles
peg
phone
pie
pillow
pinkdrink
pins
pizza
plaster
plastictriangle
pocketwatch
polarbear
potato
potatopeeler
potpuri
present
puppy
razor


redwine


remote


remotecontrol

rice

ricecake


rollers


rope


rubberbands


rugbyball

sand


scissors


scourers

screws

scrubbingbrush

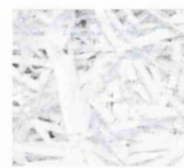

scrubbythings


sharpener


sheep


shell


shoes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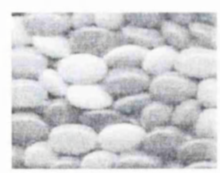
shreddedwheat


sideboard


skier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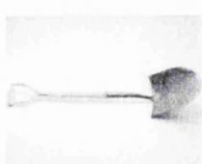
soap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sponge


sprouts

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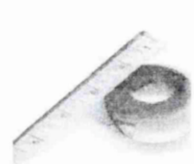
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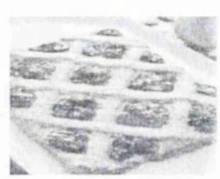
tapemeasure


taps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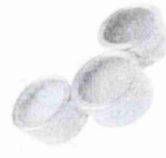
teapot


teethingring

tennis

tennisball



threecandies

tinopener

Stimuli Set for craving task [Experiment 6]

squashdrink

tea

tomatosmoothie

water