UNIVERSITY OF
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Motivational Dynamics: the interaction of motivational and affective systems on implicit processing of food stimuli

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Frequent Abbreviations

AB	Attentional Blink
AVAS	Appetite visual analogue scale
BMI	Body Mass Index
DEBQ	Dutch Eating Behaviour Questionnaire
EBA	Emotional Blink of Attention
EEG	Electroencephalogram
fMRI	Functional Magnetic Resonance Imaging
NA	Nucleus Accumbens
NPANAS	Negative scale of Positive Affect Negative Affect Scale
PANAS	Positive Affect Negative Affect Scale
PPANAS	Positive scale of Positive Affect Negative Affect Scale

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Abstract

The studies reported here were intended to examine how affective and motivational factors influence attentional processing of goal objects, such as food, by exploiting modified versions of an Emotional Blink of Attention (EBA) task originally reported by Piech, Pastorino & Zald (2010). Attentional capture by food distractors presented within a rapid serial visual stream (RSVP) was measured by the extent to which they induced an attentional blink and prevented the correct identification of a subsequently presented, specific visual target.

Initially, we explored temporal changes in attention to food images in relation to spontaneous changes in appetite that naturally occur before and after a sandwich lunch. Replicating earlier reports that fasting-induced hunger increases attention to food images, we found that attention to food depended on the level of appetite: increasing pre-prandially as hunger increased, and falling to a minimum after satiation. Moreover, changes in attention to food were seen to reflect subjective ratings of food pleasantness associated with the phenomenon of sensory-specific satiety. Notably, images of the consumed food became less distracting after lunch than images of non-consumed foods belonging to the same sandwich category or, more particularly, those representing very different food types. The EBA data also demonstrated that attentional bias for images of highly palatable, high-calorie desserts was largely immune to changing levels of appetite. Subsequent experiments confirmed that high palatability/high calorie foods with high intrinsic incentive value (cheesecake) potently capture attention even after being eaten to satiety. By contrast, satiation on palatable, sweet fruits did produce sensory-specific changes in attentional bias to fruit images in the EBA. These findings indicate that attention to food images is dependent, via separate processes, on the motivational salience and incentive value of food stimuli.

It was noted that affective state (measured using PANAS) varied with appetite level: satiety was associated with a reduction in negative affect and increased positive affect. The relationship between affect, eating motivation and attention were explored further using an ‘Affective EBA’ paradigm, in which neutral filler images within the RSVP were substituted by images of faces displaying positive or negative emotions. Positive affective priming using this technique resulted in an enhancement of attentional bias to food distractors (but not to neutral or romantic distractors). Negative priming, by contrast had no effect.

A final experiment explored whether the ability of positive affective priming to increase attentional bias to food might attenuate the previously noted, food-specific, postprandial decline in attentional capture by food stimuli. We found that in sated individuals, positive priming did produce a general increase in attention to food which was in opposition to the expected, satiety-related decline in attentional bias.

Overall, the present findings strongly support a key role for attentional mechanisms in the processes that mediate the influence of motivational and incentive salience in energizing and directing goal-related behaviours, such as food seeking and consumption.

Chapter 1: General Introduction

1.1. Background

What is motivation?

> *"Motivation is the process of arousing action, sustaining the activity in progress, and regulating the pattern of activity."*
> Paul Thomas Young (1961, p25)

Motivation was captured by the Greeks long ago with myth of Tantalus, a son of the god Zeus. According to the myth, Zeus invited his son to Olympus, and told him many secrets important to the gods. However, after leaving Olympus Tantalus discussed the secrets with others, and insulted the gods of Olympus. For this betrayal Zeus punished Tantalus, sending him to the underworld where he was tortured. Rather than physical harm, Tantalus was condemned to stand in a lake filled with fresh fruit just out of reach. Whenever he tried to drink the water receded and whenever he tried to eat the fruit would move away. Essentially, Tantalus was eternally driven by the need to consume without satiation; the myth accurately captures both the motivation to consume, and the anticipated pleasure to be derived.

Tantalus' experiences arise from the processes that energize and guide both our attention and behaviour; these processes are often collated into a single term *motivation*. This unitary concept has, over recent decades, been dissected and understood through the framework of *incentive salience*, which is a consequence of the neurocognitive interactions between the environment and the so-called, 'reward system'. This framework leads to what is commonly called motivation. Motivation underlies the activity of almost every action or decision taken by humans and other animals. Despite the fundamental importance of this system of motivation, it is surprising that such dearth of knowledge exists regarding its functioning and interactions. However, the root of this mystification is likely to originate purely through the sheer adaptability of the motivational processes. Functionally, ‘motivation’ is a multivariate process that may associate any beneficial outcomes of interactions with the environment, with particular behaviours and stimuli. For instance, humans play computer games for fun with no tangible reward other than feeling good or less stressed (Asgari & Kaufman, 2004; Charsky & Ressler, 2011; Eglesz, Fekete, Kiss, & Izso, 2005; M. D. Griffiths, 1998; Holmes, James, Coode-Bate, & Deeprose, 2009; Malone, 1981; Reinecke, 2009; Skosnik, Chatterton, Swisher, & Park, 2000), gamble for amusement (Gupta & Derevensky, 1998; Neighbors, Lostutter, Cronce, & Larimer, 2002), collect stamps for enjoyment. All of these are done merely to achieve some satisfaction, or feeling of reward - as the result of merely achieving the some arbitrary target, that has no bearing on survival. However, these behaviours and their consequences are all examples of acquired motivations. Effectively, these behaviours are irrelevant to genetic survival, but instead these behaviours and their ‘rewarding’ outcomes are learnt, recruiting underlying systems that have ostensibly developed to aid survival.

There are, of course, a plethora of targets of drives, acquired or innate, that may be investigated to understand the mechanisms underlying motivation. However, the vast majority of research has settled on investigations pertaining to two common motivational areas: hunger and substance abuse. While the latter is considered, partially, an acquired motivation focusing on the interactions between chemicals and their influence on drive and reward mechanisms, the former is innately important motivational subject. Hunger is such a powerful force that history, recent and ancient, is littered with the effects of hunger - destabilising countries and leading to wars. For example, the *Arab spring* of 2011 was largely precipitated by food shortages caused by the increases of cost in grain (Lagi, Bertrand, & Bar-Yam, 2011). In fact the key processes of evolution focus primarily on sexual reproduction, safety, and obtaining and consuming and food (Cosmides & Tooby, 2013). Hunger motivation is such a fundamental factor for survival of mammals, that hunting and foraging for food have been the largest factors influencing the evolution of hominids (Lieberman, 2006). In particular, evolution has biased the selection of ‘genes’ that provide successful cognitive and behavioural repertoires that, in conjunction with nutritional requirements, adapted to fluctuations in food availability (Chakravarthy, 2003; Eaton & Eaton, 2003; Eaton, Konner, & Shostak, 1988; Kuzawa, 1998; Loos & Rankinen, 2005; J. B. Miller, Mann, & Cordain, 2004). Evolutionary pressures and the drive to obtain essential nutrients has had a huge influence on the development of *Homo sapiens* as they appear in the world today (Lieberman, 2006).

1.2. Evolved problems: Obesogenic Environment

The environment in which of the ancestors of homo sapiens evolved was harsh and unpredictable, creating an advantage to genes which sensitised motivational systems to optimal foraging and eating strategies (Chakravarthy, 2003; Cosmides & Tooby, 2013; Lieberman, 2006) Kuzawa, 1998). For instance, neural systems, which detected food more easily, would have a greater chance of improving the survival of the individual and therefore the propagation of their genes, essentially biasing evolution towards reward-sensitive motivation systems. Furthermore, an individual who was highly biased towards reward would also be more likely to over-consume even in the absence of *extremis*. In contemporary environments these advantageous adaptations persist, although they now are considered a disadvantage to many in the parts of the world where food is readily available. The industrialisation of farming, food manufacture and free market economies has made food readily available to such a degree that food is advertised to humans. Rather than seeking out food, humans may now eat not only when they need to but when they want to - even if that is to only make them feel good. This contemporary obesogenic environment coupled with motivational systems, evolved to suit harsh environments in which the availability of food was unpredictable, has inevitably led to the obesity epidemic present in the world today (Armelagos, 2014; Lieberman, 2006; Popkin & Gordon-Larsen, 2004; E. A. Smith & Winterhalder, 1981).

In 2008 the World Health Organisation (WHO) reported that 35% of the world's population aged 20+ were categorised as overweight (BMI ≥ 25 kg/m^2), with an even distribution between both sexes. By 2014 this had increased to 39%, significant increases in developing nations, while 11-14% (> 500,000,000) of people were classified as obese (Chestnov, 2014). This epidemic is largely attributed to the over consumption of energy in relation to energy expenditure from the basal metabolic rate (BMR) and exercise. Statistics of countries experiencing obesity epidemics, such as the USA, have reported that the average intake of energy (Kcal) exceeds national recommendations required for the average individual (National Center for Health Statistics, 2010). Similar findings have been reported in the UK, with the average UK national also exceeding national recommendations for daily calorie consumption, when accounting for BMR in low activity populations, according to British Nutritional Society (Centre, 2015). Overall, this overconsumption would not be an issue if obesity was not accompanied by debilitating health issues. Being overweight or obese increases several health risks that impact on the life of the individual and society at large. In particular, obesity increases the likelihood of developing the following conditions: hypertension, heart disease, osteoarthritis, gout, sleep apnea, diabetes and some forms of cancer, amongst many other problems (Environment, 2013; Swinburn et al, 2011). In addition, the cost of medically treating obesity and its related morbidity in the UK were estimated at around £4.2 billion in 2007 (McPherson, Marsh, & Brown, 2007). The wider economic costs of obesity to the UK has been estimated at 15.8 billion per annum (McPherson et al., 2007), as a result of inactivity. The loss of life itself is perhaps incalculable.

These statistics are intended to emphasize the problems associated with a normally functioning motivational system in the contemporary world. Despite the considerable problem posed by overconsumption, there is pronounced variation in the types of foods that individuals respond to, the times that they respond to them, and how particular populations respond to food (why isn't everyone over weight?). Due to the multifaceted and complex nature of motivation there is no single unified framework that encapsulates each aspect: there is a plethora of neurocognitive and physiological interactions with the world, none of which operate in isolation. Therefore, in order to understand motivation, it is essential to look at these fundamental processes that define or contribute to it. Understanding the underlying neurocognitive processes and their influence on the processing and selection of food for consumption may provide valuable insight into the continuing global trend of weight gain.

1.3. Motivation as evolved opportunism

The ability to detect and respond to food-related stimuli was an important advantage to the survival of the ancestors of *Homo sapiens*. However, as noted above, opportunistic feeding strategies promoted by the healthy functioning motivational system have inevitably led people to over consume in obesogenic environments, particularly when that food is palatable. Underlying all of this are the motivational processes. Although motivational processing is complicated due to the nature of the world we live in, the biophysiological, environmental and psychosocial interactions ultimately depend on the same neurological architecture in the majority of mammalian organisms, including *Homo sapiens*. The predominant, current theoretical framework that explains the functioning of motivation is known as *incentive salience*, which has developed out of cognitive neuroscience. While there is debate about the precise mechanisms of the 'reward system' (Berridge, 2006; see T. E. Robinson & Berridge, 2008a), the framework of incentive salience is the most widely supported explanation of motivational processing with regards to both food consumption and addiction.

1.4. Incentive salience

The sensation of pleasure is a fundamental motive that drives individuals into pursuing rewards necessary for survival. And yet in contemporary environments the abundance of rewards such as food make the pleasure of rewards and reward seeking a maladaptive pursuit leading to behaviour such as unnecessary over consumption of food. The central factor of motivation, as described by the incentive salience theory, comes from understanding the neural circuitry of reward and its functions. Three principle psychological components have emerged from researching the ‘reward system’: wanting (process of incentive salience), liking (hedonic value/assessment), and learning (classical or instrumental associations resulting in cognitive representations)(Berridge & Kringelbach, 2015; Berridge & Robinson, 2003). While these processes may occur conjointly anytime during the ‘reward-behavior cycle’, they each tend to dominate specific phases: ‘wanting’ primarily driving the initial appetitive phase, while the ‘liking’ component dominates the subsequent consummatory phase, which plays a role in the analysis of pleasure derived from the food, and may have a role in satiety (Berridge & Kringelbach, 2008). Crucially, learning occurs throughout the motivational cycle, influencing recall of the effectiveness of behaviours of both seeking food, and the resulting outcome/pleasure derived from the eventual consumption of the motivational target.

Neurologically, ‘liking’ is thought to be primarily based in the nucleus accumbens and ventral pallidum, with research suggesting that its primary role is to measure or assign hedonic-value (level of pleasure), either anticipated or derived from consumption of a motivational target (Berridge, Robinson, & Aldridge, 2009). While this system may assign baseline hedonic values to food, changes in the ‘wanting’ system (nucleus accumbens, ventral pallidum, amygdala and ventral tegmentum) are thought to modulate hedonic values and the ‘liking’ process itself (Berridge & Kringelbach, 2008; 2015; Reynolds & Berridge, 2008; T. E. Robinson & Berridge, 2008a). Thus changes in motivational state may influence the hedonic value of food and the pleasure derived from its consumption (Berridge & Kringelbach, 2008; 2015; Epstein, Truesdale, Wojcik, Paluch, & Raynor, 2003). For instance, studies have shown that hunger state influences food ratings, with individuals rating food more positively when hungry than when sated. This interaction also influences food choices while shopping, with a greater likelihood of purchasing greater quantities of food or selecting food with more calories than individuals intended (Mela, Aaron, & Gatenby, 1996; Nederkoorn, Guerrieri, Havermans, Roefs, & Jansen, 2009).

1.5. Establishing Pleasure: Learning to ‘like’

The processes of selecting and acting on a particular aspect of the environment depends to a some extent on acquired knowledge about the relationships between actions, such as foraging, and stimuli. Although it is important to acknowledge motivational stimuli such as food have properties which engage innate and unlearnt components. Information is required for predicting rewards, anticipating responses, guiding behaviour through responses to cues, and for goal-directed action. Fundamentally, learning processes are either associative or cognitive, and the products of learning are either declarative or procedural. Learning can be broadly split across two elements stimulus–stimulus learning which encapsulates associations and are predictive of reward (Berridge & Kringelbach, 2015). And stimulus–response associations and representations of response-outcome. Generally, this kind of associative learning refers to either classical conditioning or instrumental learning. Classical conditioning is a procedural form of reward prediction, from which conditioned responses may be obtained from conditioned stimuli. Conditional responses are generally anticipatory, or conditioned motivations that are appropriate to unconditioned/naturally rewarding stimuli with which conditioned responses have become associated. For instance, food-packaging may prompt increased salivation due to individuals, consciously or unconsciously, anticipating consuming food shortly afterwards. Instrumental learning modulates behavioural responses that are strengthened or weakened by the outcome of interactions with stimuli – depending on the reinforcer. For example, an individual may focus their attention on food packaging despite being sated because the potential for highly rewarding stimuli is predicted, if the food is inside the behaviour (opportunistic foraging) is reinforced. Ultimately, learning mechanisms determine the representation of rewards, associated stimuli, and the actions to obtain them. The level of these prediction and strength of rewards are established through initial experiences, and both judged and continuously modulated by the reward system. As food is a naturally rewarding stimulus, positive associations are easily made. However, the interactions between the 'reward system', involving the development of a reward representation/memory, depend on the initial interactions that are maintained over time by further experiences, and motivational states (i.e. 'wanting') which influence the selection of information and guide behaviour.

1.6. Incentive salience and fluctuations in hedonic-value: explicit and implicit processing

Motivational and affective processes primarily occur sub-cortically, and as a consequence their influence primarily occurs implicitly (outside conscious awareness). Individuals can and do respond to motivational stimuli without awareness (Most & Wang, 2011), and, implicit stimuli have been found to influence processing. For example, subliminal presentations of happy facial expressions can increase the valence ratings of abstract visual stimuli although producing no overt change in subjective mood (Murphy & Zajonc, 1993; Wong & Root, 2003). Affectively positive subliminal cues have also been demonstrated to increase both the ratings of a beverage's pleasantness and to increase the volume of the drink consumed (Berridge & Winkielman, 2003).

Berridge and Robinson (Berridge & Robinson, 1998; T. E. Robinson & Berridge, 2008b) have demonstrated that wanting and liking involve distinct neural circuitry. Thus, stimulation of dopaminergic pathways ascending from the VTA to NAcc specifically energise ‘wanting’, and stimulate instrumental responses which lead to the consumption of rewards. This occurs independent of ‘liking’ processes. Blocking dopamine transmission in this pathway reduces goal-seeking activity but leaves hedonic responses to positive stimuli intact. Similarly, it is possible to stimulate specific neurochemical components of accumbens pathways (notably the opioid peptides) to enhance hedonic evaluation of stimuli without any impact on the organism’s desire to approach them. Incentive salience, therefore, does not account for the affective component of reward but merely the motivational process alone (Berridge & Kringelbach, 2008). However, as previously reported the incentive and affective components of motivation clearly interact: a positive experience of a stimulus gives that stimulus an increased value in future, and greater incentive salience – leading to enhanced motivation for renewed experience (wanting). Overall, the basic function of incentive salience is to associate sensory information about rewarding stimuli, and their related-cues, into attractive incentives (Berridge & Kringelbach, 2008; 2015; Berridge & Robinson, 2003; Kringelbach, 2004). Essentially, visual representations of food are initially mere perceptual representations that may possess no intrinsic motivational value. However, the interaction between the ‘liking’ components of reward and associative learning lead to the development of incentive-value. This attribution of salience is thought to be what translates a mere perceptual representation of a neutral object into a motivating/’wanted’ target (Berridge & Kringelbach, 2008).

Following the establishment of hedonic-values through learning and 'liking'/pleasure, incentive salience operates through the activation of 'wanting' components, by either endogenous or exogenous cues, interacting with associated memory. The interaction of these two processes drive motivational priority and orientate an organism to appropriate targets, without activating the pleasure/'liking' component. For instance, the feeling of hunger makes humans more likely to seek out food. According to Berridge (Berridge & Kringelbach, 2015) "motivational salience is never neutral", and neither is valence fixed. Instead, the incentive salience marks the stimulus and its cues with an intrinsic value that causes the stimulus to be more attractive than other environmentally available features, and more attention grabbing (salient). Changes in an associated motivational state are theorized to influence the overall incentive value of a motivationally-relevant stimulus and it representations. Essentially this means that increases in hunger ('wanting') should increase the incentive value and salience of food. As we will discuss below, this shift, may then be considered to enhance the ability of food-related stimuli to grab attentional processes and guide behaviour in an appropriate direction.

As motivational and affective processes may operate outside awareness to influence attention, implicit processing may allow objective investigation of these processes if they may be dissociated from subjective feelings and assessments (Berridge & Kringelbach, 2015).

1.7. Incentive salience and attention.

The intrinsic rewarding properties of food arise from, and indicate, the energy and nutrients needed for survival. Food and its related-cues develop hedonic-values that are greater than mundane or less motivationally important stimuli. Consuming food activates the NAc (associated with 'liking signal') and the orbital frontal cortex (OFC), both of which are involved with coding stimulus value (Damasio & Carvalho, 2013; O'Doherty, 2004; Reynolds & Berridge, 2008; L. Tremblay & Schultz, 1999; Winkielman, 2005). The process of assigning hedonic values evidently leads to stimuli, such as food, to be represented differently from mundane perceptual stimuli, such as brick walls. As a result, findings in cognitive neuroscience show that merely observing food increases neural activity by 24% overall, in comparison to neutral images (G.-J. Wang et al., 2004). Ultimately these hedonic value systems play a critical role in incentive salience; namely to increase the likelihood of interaction with the goal object, in this case food. The main effect of such a system would be firstly to increase implicit processing of food: through increased salience, increase attentional processing of food. While the second, and equally important function of hedonic values would be to increase the explicit evaluation of food, and its related stimuli, to increase interaction/consumption. Support for this has been garnered from a number of studies, which utilise explicit valence measures to assess the attractiveness of food and related cues. Studies investigating food valence have generally found that food is rated more positively than everyday objects or scenes (Lang & Bradley, 2007; I. Nijs, 2010; Tapper & Pothos, 2010), regardless of motivation. According to Anderson these learnt hedonic values modulate attention to food, with highly hedonic stimuli being more salient than less tractive stimuli (B. A. Anderson, Laurent, & Yantis, 2011).

This links well to incentive salience theory which suggests that the majority of this hedonic value processing occurs sub-cortically, and often below awareness, influencing both explicit and implicit levels of cognition (Berridge & Kringelbach, 2008). These motivational processes undeniably interact with neural systems responsible for allocation of attentional processing, influencing the perception of environmental features and preparing individuals to detect motivationally salient stimuli. Specifically it has been predicted that highly energizing states of motivational extremis, and levels of arousal produced by the hedonic-value of objects attract attentional faculties to particular stimuli (Mohanty & Sussman, 2013; Most, 2012). Concurrent research supports this position, with recent studies finding that the hedonic value of food compared to neutral imagery, vary in their ability to modulate neural activity in the ‘reward system’ (Frank et al., 2010). This is fundamentally critical as the interaction of motivational state and the hedonic-valuation process at an implicit level not only influence the attentional processing of food, but initiate changes in food-seeking behaviour below awareness (Ziauddeen et al., 2011).

Importantly, these differences in hedonic-values increase the salience of food-related stimuli allowing them to compete with other stimuli for attentional selection. A few studies utilising implicit measures have confirmed these assumptions, demonstrating that attention is readily drawn to food-related stimuli over mundane objects and scenes (Brignell, Griffiths, Bradley, & Mogg, 2010; Brondel et al., 2006; Castellanos et al., 2009; Mogg, Bradley, Hyare, & Lee, 1998; Werthmann et al., 2011). Additional studies have made found variance in the attentional processing of different foods relative to the palatability and energy content of food, and the level of hunger participants experience (Reynolds & Berridge, 2003; Stoeckel, Cox, Cook, & Weller, 2007; Toepel, Knebel, Hudry, le Coutre, & Murray, 2009). However these findings have also occurred regardless of appetitive state. A particularly interesting study by Nummenmaa et al (2011), demonstrated the influence of these differences in more detail. They found firstly that participants rated images of appetising food as more pleasant than perceptually matched non-food stimuli. When participants were asked to search visual arrays of 7 visually similar items for an incongruous target (i.e., food in a non-food visual array, and vice versa), food images were detected quicker than non-foods. Overall this provides support for the idea that incentive salience and motivational processing enhances the ability of appetitive stimuli to capture attentional processes in busy and complicated environments.

Further support for the influence of incentive values on attention comes from recent research conducted by Piech et al (Piech et al., 2010) investigating implicit processing, using an implicit processing task, the Emotional Blink of Attention paradigm (EBA: detailed discussion in Method chapter). The participants' task during the EBA is to detect a rotated neutral image within a rapid visual stream of similar images. However, before the target is displayed, a distracting emotional (romantic scene) or motivational image (food) is presented – designed to create a blink of attention and interfere with target identification. Piech et al (Piech et al., 2010) found that participants' attention during in the EBA task was drawn to food more readily than neutral images, but not more than romantic images, reflecting the similar explicit valence ratings of food and romantic images. Importantly, attentional capture by food stimuli was significantly increased when participants were hungry compared to when they were sated.

1.8. Motivational state: influence of hunger state and food consumption on cognitive processing.

Although 'liking' plays a crucial role in the development and maintenance of salience, most humans are not constantly consuming food. And, as found by Piech et al (Piech et al., 2010), attention to food changes relative to motivational state. The role of motivational state or drive/'wanting', according to incentive salience theory, is to regulate the urgency to act on a motivational object, such as food. Explicit ratings of food clearly show that food pleasantness is devalued by satiation, with food being devalued on average by 25% following consumption (Cameron, Goldfield, Finlayson, Blundell, & Doucet, 2014). However a common finding is a phenomenon known as 'sensory-specific satiety' (SSS) (E. T. Rolls, 2006). Essentially, pleasantness of a food decreases following its consumption to satiety, relative to unconsumed foods that are rated similarly pleasant prior to pre-satiation ratings (Berridge, 1996; Mela, 1999). This leads us to an important question: 'Does implicit processing reflect the phenomena observed in studies investigating explicit processing off food findings such as SSS?'. According to cognitive neuroscientists, the fundamental processes of motivation, 'liking' and 'wanting', often operate independently of awareness (see Berridge et al., 2009; Berridge & Robinson, 2003; Finlayson, King, & Blundell, 2007). Critically measures of explicit processing tap into conscious attitudes utilising subjective ratings of food (e.g. Brunstrom & Mitchell, 2006; Weijzen, Zandstra, Alfieri, & de Graaf, 2008). However, individuals rarely apply consciously attention towards analysing their attitudes towards food (B. A. Anderson et al., 2011; Griffioen-Roose, Finlayson, Mars, Blundell, & de Graaf, 2010). In general, behaviour is energised by changes in the motivational systems outside awareness and directed by spontaneous environmental interactions (Griffioen-Roose et al., 2010). Essentially, the 'reward system' which specifies salience biases perceptual processing towards motivationally relevant stimuli to stimulate and direct behaviour (Corbetta & Shulman, 2002; Desimone & Duncan, 1995; Serences & Yantis, 2006; Serences, Shomstein, & Leber, 2005), thereby resolving the competition between objects in our environments for attention (B. A. Anderson et al., 2011).

Selective attention, in this view, has important implications for the survival of an organism. As previously mentioned, mere hedonic value may be influential. However, recently researchers have started to investigate changes in attentional processing as a function of motivational drive/ 'wanting'. To investigate spontaneous responses to motivational stimuli, implicit measures have been developed, such as the dot probe and attentional blink paradigms. As already noted, such studies (Piech et al., 2010) have shown that not only is attention to food greater than to neutral stimuli, but that this phenomenon is stronger when participants are hungry.

Two studies have tracked these changes in attentional processing relative to appetitive state. In the first study Castellanos et al (2009) asked participants to fast for 8 hours before being assigned to either a fasted or fed condition. In the fed condition participants were given a liquid meal until they were sated. All participants completed a dot-probe task in which they were required to respond to a probe appearing after the presentation of two images: food or neutral. Participants then took part in the opposite condition a week later. The study (Castellanos et al., 2009) found that response times were slower to probes appearing under neutral images when participants were hungry compared to the sated condition. Essentially, attention was drawn towards food related stimuli when participants were hungry but not when they were sated.

Another study conducted by di Pellegrino et al (2011) investigated changes in attentional processing to food related stimuli before and after eating. In the first session of this study participants were required to respond to a SSS taste test followed by a dot-probe task. Participants were then fed one of the foods tasted in the taste test: Ritz crackers, Canestrelli cookies or bran biscuits. After eating these to satiety participants were again asked to rate the pleasantness of the food in a taste test and to again respond to the dot-probe task employing images of the food used in the taste tests. Pleasantness ratings of the food displayed typical SSS devaluations. Crucially, response times to visual probes reflected SSS devaluations with attention to the food consumed being decreased after consumption.

While both of these studies are fascinating, they each present similar problems. Firstly, they did not use foods that individuals might commonly consume for a meal. A further problem is that they quite obviously investigated attention to food, and only investigated attention to food pre and post-satiation rather than tracking changes in attention across time.

Furthermore, both studies required participants to fast, which is known to have a confounding effect on how individuals process food related stimuli (see Cameron et al., 2014).

1.9. Role of affect in motivation

Motivational processes emerging from interactions between the reward system and the environment provide a fundamental basis for understanding of how organisms are energised towards targets that promote evolutionary goals. Commonly, research has focused on hedonic value ('liking') and motivational state ('wanting') to interpret these interactions. The focus has been on internalised changes in motivational processing relative to hunger level or the value of the stimulus consumed/presented: i.e., hunger increases attention to food, satiation reduces attention to and the 'pleasantness' of food (Brondel et al., 2006). However, the environments in which *Homo sapiens* exist provide a enormity of information that inform assessments and engagement. Isen (Isen & Reeve, 2006), de Houwer (De Houwer, Teige-Mocigemba, Spruyt, & Moors, 2009), and Mengarelli (Mengarelli, 2012) have suggested that neuroaffective systems simplify endogenous and exogenous factors into affective information which influences interactions and decisions at both explicit and implicit levels. Research in cognitive neuroscience has shown that that the neurocognitive architecture of motivational and affective systems are strongly interconnected (Berridge et al., 2009; Panksepp, 2011b; E. T. Rolls, 2013; Toates, 2006) and that affective information regulates attentional processing (Carretié, Martín-Loeches, Hinojosa, & Mercado, 2001; Vuilleumier, 2005). Attentional processing has also been widely shown to be influenced by affective state and affective information (Mohanty & Sussman, 2013; Most, Chun, Widders, & Zald, 2005). Specifically, Mohanty et al (Mohanty & Sussman, 2013) has suggested that endogenous (top-down) and exogenous (bottom-up) information compete for priority to influence behaviour. However as other research has suggested the sheer quantity of information is too much to weigh the importance of each piece (Ahn & Picard, 2005; Isen, 2001; Isen & Reeve, 2006; Panksepp, 2011b). According to Mohanty et al (2013) the competition between the significance environmental and internal information is resolved, or perhaps more accurately summarised by emotional arousal relative to the endogenous affective state. In neuroscience Panksepp (Panksepp, 2011b) also suggest that affective processes may act as a gating process for sensory information. Similarly Mohanty et al (Mohanty & Sussman, 2013) suggest that affective processing or information may regulate attention toward stimuli. Essentially affective information reduces the quantity of information available into positive and negative inputs received from either the environment or within, and regulate the importance of important stimuli and therefore the attention it receives. Importantly, affective information influences implicit processing regardless of the attention grabbing properties of stimuli or endogenous motivational state (Mather & Sutherland, 2011).

Regarding the processing of food, variations in affective state are known to modify hunger (Macht, 2008). Although, oddly enough, research investigating the influence of affect on appetite has focused on investigations of negative affect, despite food consumption being generally a positive experience. This focus is likely due to the association of increased appetite or food craving related to increases in negative affect, and emotional eating – eating in response to stress. For instance, studies inducing negative affect suggest that food develops increased reward value, due to its potential to provide relief from a negative state (Bekker, van de Meerendonk, & Mollerus, 2004; Macht, 2008; Macht & Dettmer, 2006; Willner et al., 1998). Studies investigating implicit processing such as Hepworth et al (Hepworth, Mogg, Brignell, & Bradley, 2010) have found negative affect to promote attentional selection of food-related stimuli in visual-probe tasks (Hepworth et al., 2010). Similarly to Bekker et al (2004) Hepworth et al (2010) argue, that negative affect increases the hedonic value of food, leading to increases in its salience. The influence of positive effect on appetite and attention is not a consistent finding however, with studies finding that positive affect increases eating motivation (Evers, Adriaanse, & de Ridder, 2013; Evers, de Ridder, & Adriaanse, 2009; Macht, Roth, & Ellgring, 2002), decreases it (Turner, Luszczynska, Warner, & Schwarzer, 2010), or has no influence at all (Lowe & Fisher, 1983; Yeomans & Coughlan, 2009). However, positive affect is theorised to have a generalised influence to bias the evaluation of implicitly presented stimuli (Murphy & Zajonc, 1993; Wong & Root, 2003), and more specifically to increase attention towards rewarding stimuli (Tamir & Robinson, 2007). A recent study by Tamir and Robinson (2007) provided support for this. They used films to induce a positive mood in participants; after experiencing positive 'priming' attention was biased towards rewarding words in dot probe tasks, when compared to 'neutral priming'.

Affect then seems to have an important role in influencing attentional and motivational processing. However few studies have investigated the crucial role of affective processing on motivation and attentional systems, despite an abundance of affective neuroscience suggesting its importance (Berridge & Kringelbach, 2008; 2015; Reynolds & Berridge, 2002; 2003; 2008; Seibt, Häfner, & Deutsch, 2006).

1.10. Hypothesis and Aims

It is predicted that an individual will be more reactive to food-related stimuli when hungry. Following the groundwork set by cognitive neuroscience, particularly coming from the research that led to the frameworks of incentive salience and affective gating, the overarching aim of the present thesis was to investigate the hypothesis that fluctuations in motivation and affective processing influence attentional processing of food-related stimuli. This incorporates a specific investigation of attention in relation to sensory specific satiety (SSS), which has not yet been investigated with implicit measures, and attention to different food-types been compared over natural hunger cycles. Another aim of the thesis was to investigate the influence of bottom-up affective information on attentional processing. Generally, it is hypothesized that changes in both eating-motivation and affective state will lead to reciprocal changes in the attentional processing of food-related stimuli. The thesis aimed to track these processes over the time leading up to a meal and following it.

By focusing on attentional processing over the natural time course of a meal it was hoped that we could provide some of the first experimental evidence of the implicit cognitions underlying food-related motivational processing.

The primary hypotheses of the thesis are as follows:

1. Food-related stimuli will be processed differently from neutral, non-food stimuli, both implicitly and explicitly.
2. Different food-types may capture attention to varying degrees.
3. Attention to food-related stimuli will fluctuate relative to motivational state, and may reflect sensory-specific changes
4. Bottom-up affective information (primed) will influence attentional processing of food related stimuli.

Specific goals central to each chapter are as follows are as follows:

Chapter 3:

- Investigate changes in attentional processing of food relative to its consumption and changing motivational state over time preceding and following food consumption.
- Secondly to track changes in explicit measures of affective state relative to appetitive state.

- Thirdly to establish the viability of the EBA as an implicit measure for studying appetite.

Chapter 4:

- Firstly to examine to differences in attentional processing of highly appetising foods relative to their consumption and appetitive state.
- Secondly to investigate changes in affective state relative to food consumption

Chapter 5:

- To investigate implicit processing of motivational stimuli, specifically food and erotic stimuli, under affective priming conditions.
- In addition to investigate the influence of affective priming in the EBA on affective state.

Chapter 6

- To establish the influence of affective information on the implicit processing of food following satiation.

Chapter 2: General Methods

2.1. Questionnaires

Multiple measures were taken at the beginning and throughout many of the studies in this thesis. The majority of these measures were consistently employed across each of the six studies presented here; therefore the format and backgrounds of each measure are described in detail in this instance only. In particular, this chapter will detail and provide the rationale for each of the measures described, as well as their psychometric properties.

2.2. Appetite Visual Analogue Scale (AVAS; Blundell et al 2010)

The AVAS was used at the beginning of each experiment to assess participants' level of eating motivation. The AVAS requires participants to rate 4 items related to subjective level of hunger, appetite and satiety, each using a 100 mm visual analogue scale (VAS), between two anchoring terms: 'Not at all' and 'Extremely'.

Hunger, appetite and satiety are known to have objective and subjective components. However, individuals are likely to aggregate these terms to describe the subjective experience of them as a single sensation used to gauge when to alter behaviour (i.e., feeling hungry provokes food seeking). Past research has shown that the sensation of hunger differs quantitatively and qualitatively between individuals (Monello & Mayer, 1967). In particular, a study of 603 individuals, conducted by Monello and Mayer (1967), found no clear pattern of traits, sensations or characteristics that typified hunger (Monello & Mayer, 1967). Essentially, measuring hunger-related motivations within subjects is currently considered the best method of gauging appetite. Since hunger is a subjective construct, the most appropriate measure of hunger is its subjective expression at a given time

(Stubbs et al., 2000). As a consequence, scales for assessing hunger motivation are based around recording changes within a participants arbitrary self-assessment of state, using VAS. Visual analogue scales are commonly used in studies of appetite (de Graaf, Schreurs, & Blauw, 1993; Hill & Blundell, 1983; Hill, Magson, & Blundell, 1984) for recording changes in appetite. Generally VAS provide a simple and fast method for participants to record their subjective appetite state in a quantifiable way, that also allows for within-participant discrimination over time, whilst simultaneously giving researchers a quantifiable measure of these internalized states that can be compared between participants due to the standardized nature of the format. The studies presented in this thesis utilized a shortened version of an appetite measure taken from Hill & Blundell (1982), which contained four items: ‘How hungry do you feel?’; ‘How full do you feel?’; ‘How strong is your desire to eat?’, and ‘How much do you think you could eat now?’. An investigation of this measure by Reid et al (1998) using principal component analyses found that the average of the questionnaire item scores was the best measure of appetite, explaining 85% of the variation observed, and accounting for general motivation to eat and a sense of gastrointestinal repletion. This finding influenced our decision to use average AVAS scores.

The reliability and validity of VAS-based appetite measures has been difficult to gauge, as subjectively-expressed hunger is strongly influenced by individual differences (Stubbs et al., 2000). Inter-subject variation accounts for 50% of the variance in participant responses, meaning that AVAS should be analysed using within-subject comparisons (Stubbs et al., 2000). Furthermore, the AVAS is consistent within participants across different testing sessions, for instance Lappalainen et al (1993) found no differences between AVAS ratings within-participants over three separate sessions with identical meals. The test-retest reliability of AVAS is, therefore, high in within-participant studies with correlation coefficients ranging from .75 to > .90 in some cases (Cohen and Vinson 1995; Sobell et al. 1986).

2.3. Positive Affect Negative Affect Scale: Visual Analogue (PANAS; Watson, Clark and Tellegan, 1988).

The PANAS questionnaire is a 20-item self-report measure of: 10 positive (PA) and 10 negative affective (NA) items. Scores from are either totalled or averaged across the 10 items of each scale. The PANAS was administered, in pen and paper form (P&P), to assess changes in mood. It is generally considered that most of these affects/feelings may be broadly defined between two underlying constructs: positive affect (PA(and negative affect (NA). Positive affect is understood as the extent to which individuals experience endogenous or/and exogenous pleasure from interactions between the environment and intrinsic state. While high levels of NA are epitomized by distress and displeasure from engagement between the individual and their environment. Essentially, high levels on either scale are considered to reflect the activation of positive or negative affect, while low levels are merely the absence of these feelings (Watson, Wiese, & Vaidya, 1999).

As a tool to measure mood, the PANAS scale has been found to have strong internal consistency. Crawford et al (Crawford & Henry, 2004) found a high reliability, between .85 and .89, in a large study of 1003 participants. Furthermore, the PANAS has been found to have high test-retest reliability, whilst also having high cross-cultural validity (Thomson, 2007). It is, therefore, an effective measure for studying changes in affective states between participants and over time.

Previous versions of the PANAS have utilized 5-point Likert scales; the present study replaced these with VAS as they are generally considered to have high correlations with Likert scales (Bolognese, Schnitzer, & Ehrich, 2003), whilst having greater sensitivity to state based changes over time

(Grant et al., 1999; Hasson & Arnetz, 2005).

2.4. Dutch Eating Behaviour Questionaire (DEBQ; van Strien, Frijters, Bergers, & Defares, 1986)

The DEBQ was used in four of the studies, in order to assess trait-based differences between participants. The DEBA focuses on three factors that impact on food consumption: restraint, emotional eating and external eating. *Restrained eating* theory attributes overeating to dieting (Polivy & Peter Herman, 1976). This measure comes from the paradox that individuals who are 'dieting' homeostatically preserve body weight. However, restricting food intake to reduce body weight engages physiological defences, such as lowering the metabolic rate (Goldsmith et al., 2009; Major, Doucet, Trayhurn, Astrup, & Tremblay, 2007) and arouses a persistent state of hunger. This state of self-control may be compromised if the 'dieter' experiences disinhibiting substances or events/feelings, such as alcohol, anxiety, depression - or even the consumption of high-calorie foods. Essentially, inhibitions/restraint to diet may easily be abandoned after experiencing disinhibition (Herman & Polivy, 2004). Counter-regulation may then occur, resulting in excessive food intake (Polivy & Herman, 1985). As a result, intense dieting may lead to patterns of overeating (*Emotional* or *External eating*), as arousal and external stimuli are also known to disrupt the cognitive restraint exercised by dieters experiencing persistent hunger (Herman, Van Strien, & Polivy, 2008).

The DEBQ was developed to measure the three factors influencing food consumption. It is comprised of 33 items that utilize Likert-type scales ranging from 1 = seldom to 5 = very often. The Emotional Eating component of the DEBQ is comprised of 13 items (e.g., "Do you have the desire to eat when you are irritated?"); the External Eating component utilizes 10 items (e.g., "Do you eat more than usual when you see others eating?"), as does the Restraint scale (e.g., "Do you deliberately eat less in order to not become heavier?”). Only one item is reversed in the whole scale, item 21 of the external component (“Do you find it hard to resist eating delicious foods?”).

Analyses of the three scales of the DEBQ has found them to have good psychometric properties, with good internal structure (21-47%), reliability (0.90-0.94) and predictive validity (21-47%) (Bozan, Bas, & Asci, 2011; Lluch et al., 1996; Van Strien & Van de Laar, 2008; Wardle & Beales, 1987).

2.5. Labeled Magnitude Scale (Pleasantness/valence VAS; (Lishner, Cooter, & Zald, 2008)

Labeled magnitude scales were used throughout the thesis, as explicit measures of pleasantness for visual stimuli. These were used to assess the valence of images as well as changes in pleasantness that may occur due to manipulations of appetitive state or after affective priming. In each valence task, participants rated 10 images of each category type used during the emotional blink of attention tasks (e.g., fruit, cheesecake, positive affective facial images, etc). Images were randomly selected from their respective image banks, with each image being rated for pleasantness (valence) and arousal using a labelled magnitude scale (Lishner et al., 2008). The images were presented with 100 mm visual analogue scales, anchored with the terms ‘Extremely pleasant’ and ‘Extremely unpleasant’, on which participants indicated their ratings of the images. These terms were used as they convey maximal intensity (Lishner et al., 2008).

Measures like these have been used in a variety of experiments investigating pleasantness (Krieglmeyer, De Houwer, & Deutsch, 2013; Krieglmeyer, Deutsch, De Houwer, & De Raedt, 2010), and specifically in studies investigating attentional processing (Piech et al., 2010) and hunger motivation (Blechert, 2014; Killgore & Yurgelun-Todd, 2006; Krieglmeyer et al., 2010; Stoeckel et al., 2007).

2.6. Attentional Measures

Selective attention
The mammalian brain has a limited processing capacity. As a result, environmentally available perceptual representations must compete, or rather be selected by attentional systems, for further processing. Competition for attention is resolved by selective attentional processes, with perceptual biases typically favouring motivationally relevant (salient) stimuli (Corbetta & Shulman, 2002; Desimone & Duncan, 1995; Serences et al., 2005; Serences & Yantis, 2006). The outcome of attentional selectivity is two-fold: *attentional capture* and *inattentional blindness*. Inattentional blindness, is a phenomenon whereby an individual fails to notice stimuli presented inside their visual field while cognitively preoccupied with an attentionally demanding task (Mack & Rock, 1998). When a stimulus is selected involuntarily, that stimulus has captured attention. This capture can present an adaptive advantage when a stimulus signals danger or opportunity (Laurent, 2008). Regarding food, this can be apparent in the inability to maintain attention on a task when a food-related stimulus is presented.

For the purposes of this thesis, attentional capture was operationalized as…

> ”*Salient but task-irrelevant stimuli have been found to slow visual search for a target in a spatially-specific manner (e.g.,* (B. A. Anderson & Folk, 2010; Hickey, McDonald, & Theeuwes, 2006; Theeuwes, 2010; Theeuwes & Godljn, 2002)*); this is known as salience-based attentional capture.*” (B. A. Anderson et al., 2011).

The combined influence of attentional capture and inattentional blindness has resulted in Rapid Serial Visual Presentation paradigms (RSVP) becoming a popular measure for investigating attentional processing of environmentally available stimuli (discussed below). Failures in attending to visual targets in these tasks is used as a measure of attentional capture by another distracting visual stimulus, such as a food image presented shortly before a task-specific target stimulus.

Measuring attentional selection

2.7. Emotional Blink of Attention (EBA; (Most, Smith, Cooter, & Levy, 2007))

The attentional blink task is a recently developed cognitive measure of implicit processing. The measure was first developed after Broadbent and Broadbent (D. E. Broadbent & Broadbent, 1987) discovered attentional blinks (AB (inattentional blindness)) when presenting participants with RSVP streams of words containing two targets, defined as either a category or letter case. Broadbent and Broadbent found that on trials where the first target was reported correctly, identification of the second target was impaired when it appeared within 500 msec after the presentation of the first target. An effect known as attentional blink (Raymond, Shapiro, & Arnell, 1992). Similarly, Raymond et al (Raymond et al., 1992) assessed identification of two targets amongst stimuli (black letters) presented at 100 ms per item in a RSVP of letters. The participants' task was to name a single white letter (Target 1) and detect the presence or absence of a black letter "X" (Target 2). It was found that correct identification of Target 1 impaired identification of Target 2 when it appeared within 500 msecs of Target 1. Importantly, this 'attentional blink' effect was significantly reduced when participants were told to ignore Target 1. The finding that the same visual stimuli yielded different responses as a result of task requirements, showed that AB resulted from attentional limitations rather than sensory factors. These RSVP tasks cause inattentional blindness by temporally exhausting cognitive resources due to target processing, which leads to participants missing the second target (Lavie, 2005). Although these missed targets may be processed post-perceptually (Dux & Marois, 2009).

Although attention blinks occur in response to cognitive demands, individuals are prone to attending to emotional stimuli even when they are task irrelevant (e.g. Most et al., 2005; Vuilleumier, 2005; Vuilleumier, Armony, Driver, & Dolan, 2001). Commonly, studies use response times to infer the degree of emotional facilitation or interference (Field & Cox, 2008; Fox, Russo, Bowles, & Dutton, 2001; MacLeod, Mathews, & Tata, 1986; Ohman, Flykt, & Esteves, 2001). Attended stimuli are typically processed quickly and accurately, while unattended stimuli typically remain unnoticed even when presented to the visual field {Chun & Marois, 2002; Mack & Rock, 1998; Most, Scholl, Clifford, & Simons, 2005; Most et al., 2001}.

Crucially, attention to task irrelevant stimuli induces a temporary visuo-attentional impairment (Most et al., 2005) when stimuli are particularly salient, such as threatening images. This effect may occur even when participants are required to ignore irrelevant stimuli or actively search for other stimuli (Piech et al., 2010). While original RSVP tasks required participants to detect two targets which create *attentional blinks* (AB), the current literature has reported that attentional blinks may occur when individuals search for single targets (Asplund, Todd, Snyder, Gilbert, & Marois, 2010; Barnard, Scott, Taylor, May, & Knightley, 2004; Folk, Leber, & Egeth, 2002; Most et al., 2005; Pashler & Shiu, 1999).

More recently emotional or motivationally relevant stimuli within RSVP streams have been found to elicit spontaneous attentional blinks despite being task irrelevant. In these Emotional Blink of Attention (EBA) paradigms, participants are presented with numerous RSVPs; in each stream the participant’s task is to detect a rotated image and to identify its rotation. Studies with food (Piech et al., 2010) and threating (Most et al., 2005) images, have both found that participants display attentional blinks when motivational or emotive images are presented before rotated targets. These effects occur even when participants were offered monetary incentives to avoid being distracted (Piech et al., 2010).

The EBA task is conceptualized as an attentional selection task, with stimuli competing for space within the limited attentional capacity of individuals (Most et al., 2005). It is possible that attentional blinks may only occur when stimuli compete within common capacity-limited attentional resource. The more attention that is deployed for a distractor, either because it is more salient or task relevant, the less capacity is available to process subsequent targets (see Dux & Marois, 2009). Neuroimaging evidence supports this, with attention blink manipulations activating frontal-parietal area responsible for attentional allocation (Colzato, Slagter, Spapé, & Hommel, 2008; Hommel et al., 2005; Marois & Ivanoff, 2005), and supporting the view that attentional blinks represent a deficit of selective attention. This makes the EBA an important measure of implicit processing, as attention is regarded…

> "*…as the mechanism by which motivationally relevant stimuli, such as targets, are selectively processed over other items, such as distractors* (Pashler & Shiu, 1999). *Thus, any stages of information processing that are involved in achieving that behavioural goal may be the recipient of attention, and hence contribute to the attentional blink deficit*." Most (Most et al., 2005).

Adapted Emotional Blink of Attention (aEBA, Affective Priming).

The influence of affective stimuli on attentional processing has been well established, with research generally finding that stimuli rated as having high affective salience capture attention to a greater extent than neutrally rated stimuli. Recent examples show that individuals preferentially attend to emotional faces based on salience ratings (Calvo & Nummenmaa, 2008; Vermeulen, Godefroid, & Mermillod, 2009), whilst observing images of others displaying facial expression of fear or disgust also impacted on attentional processing in observers (T. Stein, Zwickel, Ritter, Kitzmantel, & Schneider, 2009; Vermeulen et al., 2009). Other studies have found affective state can influence the speed of affective processing. For instance, Vermeulen et al (Vermeulen et al., 2009) found that negative state reduces the attentional processing of affective stimuli. This is theorized to occur as a result of negative states inducing systematic/analytical processing, while positive affect favours automaticity (Schwarz & Bless, 2007). A study investigating the impact of affective state on attentional processing was carried out using an attentional blink paradigm (Vermeulen, 2010). Similarly to the theoretical position outlined by Bless and Schwarz (Schwarz & Bless, 2007), Vermeulen discovered that a participant's affective state moderated attentional process. Specifically, positive affect improved task performance while negative affect decreased target (T2) detection. Importantly these and other findings demonstrate that inducing affective states can influence attentional processing (Jefferies, Smilek, Eich, & Enns, 2008; G. Rowe, Hirsh, & Anderson, 2007).

Many studies inducing affective states typically use film clips or music. However, emotional priming can be achieved using only brief presentation of affective imagery. Such visual priming provides the possibility of investigating the impact of affective information on attention to other stimuli. For instance, in a classic experiment Murphy and Zajonc (Murphy & Zajonc, 1993) presented participants with human faces expressing different emotions. These brief presentations of facial images were sufficient to influence the valence ratings of Chinese characters (ideographs); an effect which has been subsequently reproduced in a replication of the original study (Wong & Root, 2003). With regards to attentional studies, affective primes presented for 200 ms in an attentional blink paradigm have been found to influence the affective assessment of nonsense target stimuli (Raymond, Fenske, & Tavassoli, 2003).

Based on the apparent power of briefly presented emotional images to influence psychological responding, we explored this phenomenon in relation to the possibility of influencing attention to emotionally or motivationally salient stimuli. No previous version of the EBA had specifically incorporated emotional primes, therefore we constructed an EBA task to investigate the influence of affective priming on detection of a motivationally salient target (food images).

We adapted the EBA task outlined by Piech et al (Piech et al., 2010). This consisted of several RSVPs, with the participant's task being to detect a target image rotated on its side within the stream. Motivationally salient or neutral distractor images were incorporated in each stream in order to produce an attentional blink. As outlined in more detail in the following chapters, the inclusion of emotional facial images (primes) within the RSVP before distractor presentation was found to exert a marked effect on target identification accuracy. We subsequently explored the extent to which the number of prime images was critical to this effect.

2.8. Pilot: Comparing the Quantity of Affective information to influence attentional processing in RSVPs

A pilot study comparing the influence of the quantity of affective information required to influence attentional blink responses to RSVPs tasks used in the EBA method set out by Piech et al (2010) was conducted. The primary purpose of this was to determine the number of affective images within streams required to produce a priming effect. The primary differences from the study set out in the original paper and the present pilot were that filler (landscape scenes) images used in the study were replaced in with varying numbers of affective images.

2.8.1 *Method*

Participants (n = 28) were exposed to 4 blocks of 50 RSVPs (trials). Within each block visual streams of 17 images (each presented for 100 msec) were spit into two types, streams with neutral or food distractors. The majority of streams had positive affective images (smiling faces) (see figure 2.8.1).. The numbers of positive primes preceding the distractors were: 0, 2, 3, 5 or 7. Number of primes and distractor types were distributed equally across the four blocks, with random selection of stream type within each block.

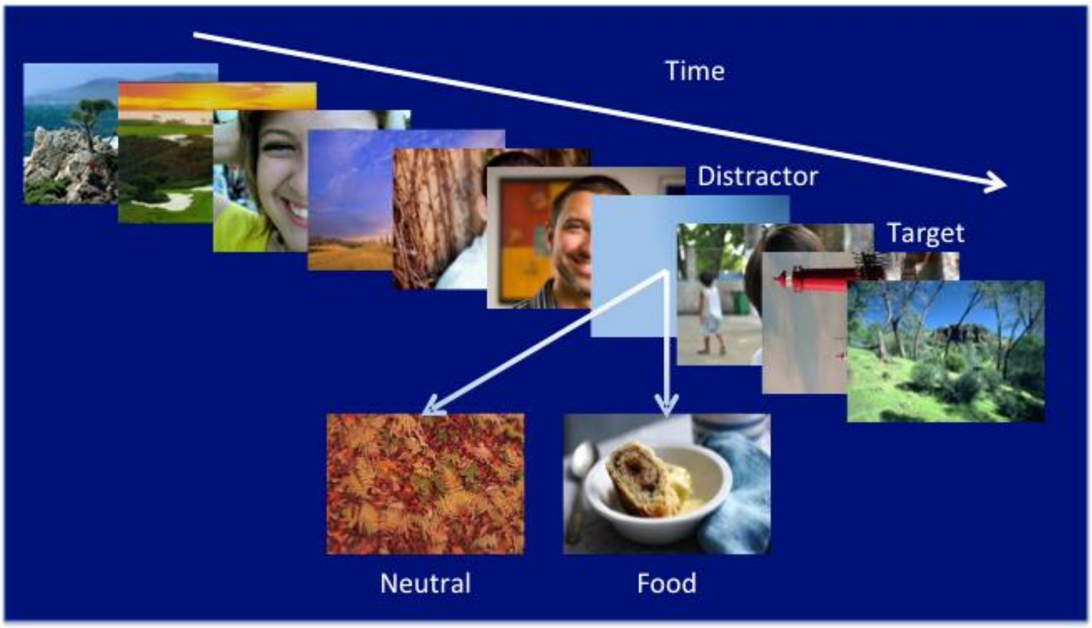


Figure 2.8.1. Diagram of EBA summation task with positive primes.

Note. positive images varied as mentioned above 0 to 7 positive images.

2.8.2 *Procedure*

Participants were tasked with detecting a target images rotated on its side. And responding to questions asking to respond as accurately and quickly as possible to the questions: ‘Did you see the picture rotated on its side?’, and ‘Did you see the image rotated on its side?’ appearing after each RSVP. The reaction time and correctness of each response were automatically recorded for each stream.

2.8.3. Results

Analysis of correctness of response, showed that positive primes had a significant influence on the ability of distractors to capture attention (F(1,276) = 30.49, $p < 0.001$, partial $\eta^2 = 0.1$), while the number of primes also had a small influence on target detection (F(4,276) = 3.97, $p < 0.01$, partial $\eta^2 = 0.03$). Although the interaction didn’t show a combined influence (F(4,276) = 0.75, $p = 0.55$, partial $\eta^2 = 0.01$). Interestingly, as the number of primes increased target detection accuracy decreased on streams with food images, while neutral images were unaffected (see Fig 2.8.2).

Table 2.8.1. Pairwise Comparisons of Average Target Detection Accuracy: Distractor Type X Prime Number

			Correct response Mean ± SD		Statistics	
No. Positive Primes	Distractor 1	Distractor 2	Distractor 1	Distractor 2	t-value	*p-value*
0	Neutral	Food	80.58 (14.47)	71.88 (16.33)	2.64	0.01
2	Neutral	Food	80.13 (12.27)	75.00 (12.38)	2.03	0.05
3	Neutral	Food	81.25 (11.15)	68.53 (14.28)	3.99	<0.001
5	Neutral	Food	74.57 (14.23)	60.27 (20.71)	4.48	<0.001
7	Neutral	Food	75.45 (17.51)	66.52 (17.70)	2.5	0.02

Note. df=27.

Primes had little effect on accuracy within trials with neutral distractors. However, decreases in performance occurred in food distractor trials that showed some relation to the number of primes presented-before the distractor. Interestingly, target detection was only reliably affected after 3 or more primes were presented in streams with food distractors: two compared with three (t(27) 2.57, p = 0.02, r = 0.44); three compared with four (t(27) 2.42, p = 0.02, r = 0.42); four compared with five primes (t(27) -1.59, p = 0.12, r = 0.29).

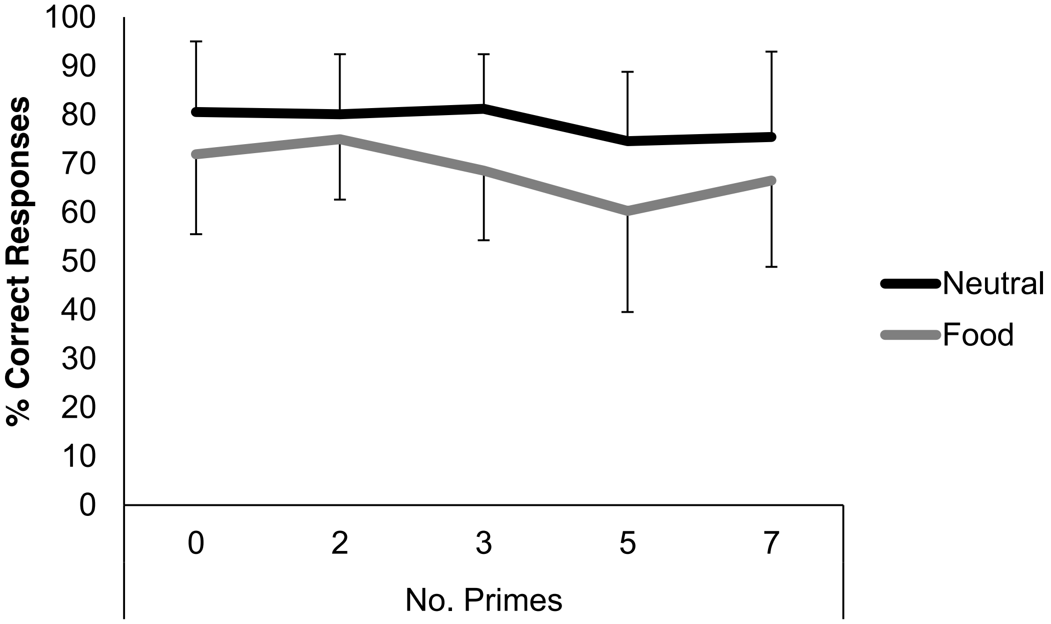


Figure 2.8.2: Comparison of target detection between distractors by number of positive primes

The affective priming EBA was found to have no influence on hunger (t(27)-1.46, p= 0.16, r = 0.27). Although affective priming appeared to have some influence on self-reports of positive (t(27)3.76, p< 0.001, r = 0.59) and negative (t(27)2.39, p= 0.02, r = 0.42) affect, pre and post EBA. Specially reductions in negative affect and increases in self-reports of positive affect.

Overall, the pilot data indicate that the distribution of primes preceding distractors within EBA streams was always sufficient to exert its potentiating effect on food-induced attentional blinks.

Chapter 3:

Temporal changes in attentional bias to food reflect sensory-specific satiety: satiety as inattention to food

3.1. Introduction

A broad range of studies have demonstrated that we possess an innate attentional bias for food stimuli, such that there is a preferential allocation of cognitive resources to the detection of nutritive items within our environment. Moreover, as might be expected, the ability of food to capture our attention is enhanced when our motivation to eat is increased. Thus, while a preferential bias toward food is evident even in the absence of need (e.g. Nummenmaa et al., 2011), experiments using a variety of spatial and temporal attentional tasks have found that being hungry increases attentional bias to food-related stimuli in Stroop, visual probe, eye-tracking and attentional blink paradigms (Castellanos et al., 2009; Channon & Hayward, 1990; Lavy, van Oppen, & van den Hout, 1994; Loeber, Grosshans, Herpertz, Kiefer, & Herpertz, 2013; Mogg et al., 1998; I. M. T. Nijs, Franken, & Muris, 2009; Piech et al., 2010; Placanica, Faunce, & Soames Job, 2002).

An important consideration when considering how attention to food might vary in relation to meal taking is that satiety is not an absolute phenomenon. The termination of eating of a particular food might be associated with subjective reports of a reduced desire to eat or feelings of fullness, but a recrudescence of the motivation to eat and further consumption are easily induced by the presentation of new, tempting foods – commonly referred to as the “dessert effect”. This phenomenon, which relates directly to the impact of the hedonic evaluation and incentive salience of food, is known as sensory-specific satiety (B. J. Rolls, 2009; B. J. Rolls, Rolls, Rowe, & Sweeney, 1981). Sensory-, or food-specific satiety refers to the observation that the pleasantness of the sight and taste of a food that is eaten to satiety declines compared to other positively-evaluated foods that have not been consumed. Consequently, appetite may be prolonged and overconsumption stimulated by the availability of a variety of, particularly highly palatable, foods: a phenomenon that is apparent in buffet meal situations, and which underlies the division of meals into distinct courses that is found in many cuisines (Havermans, Janssen, Giesen, Roefs, & Jansen, 2009; Hetherington & Rolls, 1996; Remick, Polivy, & Pliner, 2009).

In relation to attentional bias to visual food stimuli, sensory-specific satiety might be predicted to be reflected in changes in the ability of different foods to capture our attention, dependent on their relative motivational or emotional (hedonic) salience, and to be linked to the consumption of particular foods. To date, this possibility has been investigated in only a single study (di Pellegrino et al., 2011). Di Pellegrino and colleagues used a visual probe task to assess attention to pictures of two palatable test foods (crackers and cookies, that were initially rated to have equivalent levels of pleasantness). Attentional bias to the food stimuli was assessed in 6-hour fasted participants, before and after they had eaten to satiety on one of the foods. Before eating, the two foods were able to capture attention to a similar degree. However, after satiation there was a marked attenuation of attentional bias to, and reduction in pleasantness ratings of, the food that had been consumed. Moreover, for the food that had been consumed, the greater the reduction in its reported pleasantness, the greater was the reduction in attentional bias. Thus, the authors concluded that the transitory changes in the relative preference for different foods that characterize sensory-specific satiety are mirrored by adjustments to the allocation of visual attention, away from food that has been recently consumed and that is consequently hedonically devalued (di Pellegrino et al., 2011). For the omnivore, such a mechanism would favour the optimal exploitation of a range of available food resources and promote a varied diet, so avoiding potentially injurious overconsumption of a single food and maximising the opportunity to meet the requirement for essential nutrients and energy (Kirkham, 2009; B. J. Rolls et al., 1981).

So far, studies into the relationships between eating motivation and attention to food have simply contrasted responses in individuals who are either fed (sated) or fasted. In the majority of cases, hunger has been induced through quite lengthy fasting – for as long as twenty-four hours. While such extreme manipulations are clearly effective in increasing appetite, they are hardly typical of the everyday, spontaneous fluctuations in eating motivation that accompany typical, habitual meal patterns. An additional limitation of some previous studies is their use of different groups of participants to compare hungry or sated attentional responses; or, when the same individuals have been tested, fasted and fed conditions commonly did not occur in the same experimental session.

In the present study, we were concerned to investigate the extent to which attentional bias to food cues is linked to the rise and fall of appetite that naturally precede and follow food consumption at predictable mealtimes. Consequently, we monitored naturalistic temporal changes in these variables before and after an *ad libitum* lunch, in individuals who attended the laboratory without any prior restriction on their food intake and who followed their normal breakfasting routine. In addition, we wished to further characterize the attentional correlates of sensory-specific satiety. Accordingly, we adopted the emotional blink of attention (EBA) methodology of Piech et al (Piech et al., 2010), in which the presentation of a task-irrelevant, motivationally or emotionally salient distractor image within a rapid serial visual presentation (RSVP) induces an attentional blink that reduces one's ability to subsequently detect a specific target. Using this technique, those authors successfully demonstrated that food distractor images more effectively induced an attentional blink in participants when they were fasted, compared to when they were sated. In the experiment described here, the EBA task was repeated at regular intervals both before and after a sandwich lunch, in which participants consumed a pre-selected, preferred sandwich to satiety. Within successive RSVP streams, distractor images included photographs of either the specific type of sandwich that would be eaten at lunchtime, photographs of sandwiches with fillings that would not be consumed, or pictures of desserts. Thus, we were able to assess the temporal variation in attention to food in general, against changing levels of pre- and post-prandial eating motivation, and also assess adjustments in the relative attentional bias to the different categories of consumed or non-consumed food that might reflect sensory-specific satiety. Attentional processing was tracked across time: two hours before, and one hour following food consumption.

3.2. Method

3.2.1. Participants

Thirty normal weight adults (12 males, 17 females; BMI = 24.33) aged between 18 and 40 years (23.38 ± 3.73) were recruited from the University of Liverpool campus and the surrounding community, using advertisements and opportunity sampling methods. Participants were required to have normal or corrected-to-normal vision, to be non-smokers, non-dieters and habitual lunch eaters. Exclusion criteria included the recent or current use of any medication that might affect appetite or attention, or any food allergy or intolerance. Volunteers were informed that the study was investigating how people's attention to motivationally significant stimuli change over time, in relation to fluctuating motivational state; but no specific reference was made to the central focus on changes in attention to food in relation to the motivation to eat. Participants were financially reimbursed for their involvement in the experiment. Ethical approval for the study was obtained from the University of Liverpool's Institute of Psychology, Health and Society Ethics Committee.

3.2.2. Emotional Blink of Attention Task: The study adapted the emotional blink of attention (EBA) paradigm previously reported by Piech, Pastorino & Zald (Piech et al., 2010), using a modification of the original software generously provided by Dr Richard Piech.

The EBA task consisted of repeated trials within which the participant was required to detect a target amongst a series of images presented within a rapid, serial visual stream presented on a computer screen using an E-Prime program. On each trial, the visual stream comprised 17 successive images, serving as either a filler, distractor, or target (see Fig. 3.2.1). Each image in the stream was presented for 100 ms, with no delay between successive images. Distractor (neutral or food) images could appear randomly at any point within the stream, after the presentation of at least 3 fillers (landscape images). Target images (landscape images rotated 90° degrees either clockwise or counter-clockwise) were displayed either 200 ms or 400 ms after the onset of the distractor (2- or 4-lag). At the end of each stream participants were required to indicate, by key press in response to screen prompts, whether they had seen the target and, if they had, whether it was rotated to the left or right. Participants were instructed to answer as quickly as possible. Only trials for which the participant reported seeing the target and correctly indicated its rotation were counted as correct. The reaction times for responses to these questions, and response correctness were recorded by the software. On each test occasion, participants were exposed to 4 blocks of 34 streams (trials), with a 1-minute rest interval between successive blocks. The different distractor categories were distributed within each block.

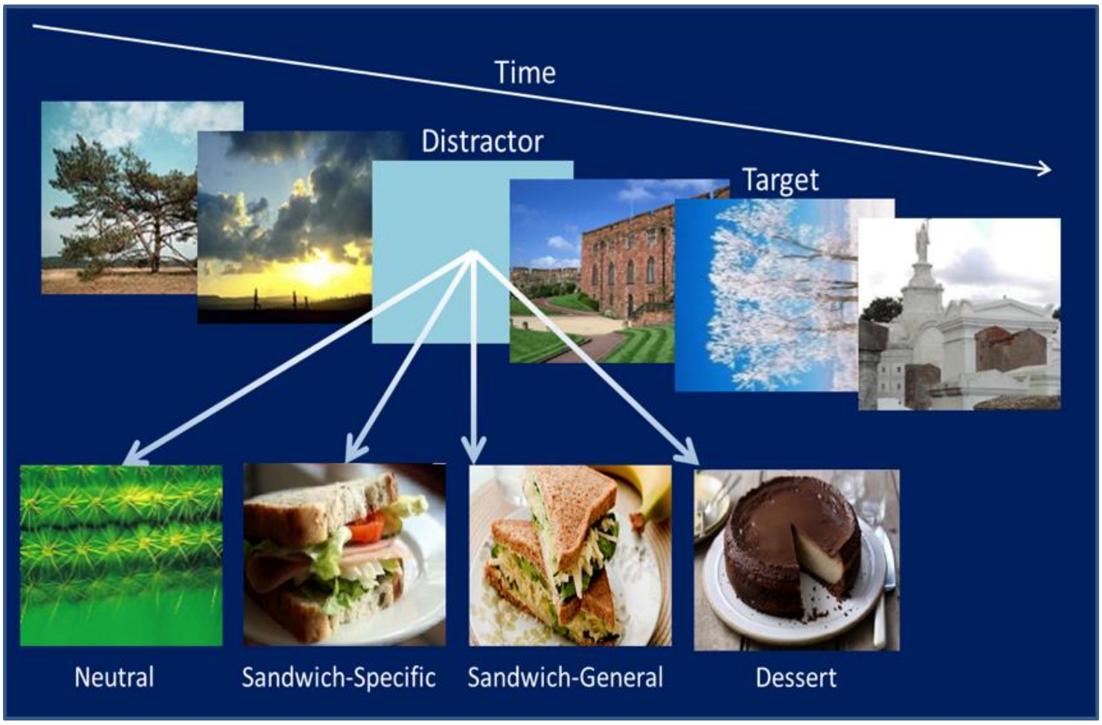


Figure 3.2.1. Diagram of EBA task, with different sandwich categories

3.2.3. Visual stimuli: A total of 854 colour, luminance-matched, photographic images were used, each presented on screen in a 95 mm wide x 75 mm high format, viewed at a distance of approximately 500 mm. Images were taken from the International Affective Picture System (IAPS) databank (Lang, Bradley, & Cuthbert, 2008), and provided the image database used by Piech et al (2010), supplemented by photographs of food prepared specifically for this study. The fillers were selected from 252 images of landscapes and urban scenes. The targets were drawn from separate banks of similar scenes rotated either 90° to the left (136) or right (135). Neutral distractors were 48 images selected from the IAPS, depicting commonplace objects chosen from IAPS for their low arousal and neutral valence ratings (see Lang, Greenwald, Bradley, & Hamm, 1993). Food distractors belonged to one of three categories: sandwich-specific, sandwich-general, or dessert. Thirty sandwich-specific images represented the particular sandwich type that each participant had selected to eat for their lunch, taken from a range of different perspectives with the filling being easily identifiable in each. Sandwich-general distractors were drawn from

150 equivalent photographs representing 3 other sandwich types. Dessert distractors were selected from 52 photographs of appetizing desserts.

3.2.4. Procedure

Participants arrived at the laboratory at 10:00 for preliminary screening to ensure compliance with inclusion and exclusion criteria, and to complete the informed consent procedure. No specific instructions about eating or food consumption were given before the study, other than to indicate to the participants that they should not bring food to the laboratory as a sandwich lunch was to be provided. Prior to the test session, participants were asked to select their preferred sandwich from a choice of four commonly eaten varieties of filling. Sandwiches were obtained from a national supermarket chain. Participants were required to remain within the laboratory for the duration of the experiment, but during the intervals between testing sessions, participants were allowed to relax in a lounge area where they had access to computers and the internet, along with a range of reading material and a television.

Initially, participants completed the Positive Affect Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) and an appetite visual analogue scale (AVAS; adapted from Blundell et al, 2010). The PANAS requires participants to indicate the extent to which each of 20 different affective terms explain how they feel, rated on a 5-item Likert scale, anchored by ‘Not at all’ and ‘Extremely’. The AVAS comprised of 4 appetite-related items (‘How hungry do you feel?’ ‘How strong is your desire to eat?’ ‘How full are you’, and ‘How much food do you think you could eat?’), and 8 questions recording levels of general motivation (‘How strong do you feel right now?’, ‘How determined are you?’). The questionnaire utilised a 100 mm VAS to record responses to each item, anchored with the terms ‘Not at all’ and ‘Extremely’. A single AVAS score was derived from the sum of ratings on the

4 appetite items, with a potential maximum score of 400 indicating the highest level of motivation to eat. Additionally, participants completed a valence task in which they were asked to rate the pleasantness of 50 images selected from each of the following categories (10 of each): landscape/fillers, neutral, sandwich-specific, sandwich-general and dessert. The images were rated on a 100 mm visual analogue scale, anchored with the terms “not at all attractive” and “extremely attractive”.

Having completed these initial ratings, participants undertook the first EBA session. Subsequently, over the course of 4 hours, the AVAS, PANAS and EBA were repeated on 7 occasions, each separated by a 40-minute interval. Two hours after the start of testing (between 12:00 and 13:00), participants were given lunch, comprising their preferred, pre-selected sandwich and water to drink (see Table 3.2.1. for testing schedule). Each participant was provided with 4 identical sandwiches, presented on a plate, and were invited to eat as much, or as little, as they wanted. Testing recommenced 40 minutes later, as described above. Both before and after lunch, and again after the final test session, participants repeated the valence test to rate the attractiveness of the images originally shown to them at the beginning of the experiment. Finally, the participants were debriefed as to the purpose of the study and released from the experiment.

Table 3.2.1: Schedule of testing

Time (min)	AVAS	PANAS	EBA	Valence	Lunch
0	▨	▨	▨	▨	
20					
40	▨	▨	▨		
60					
80	▨	▨	▨		
100					
120	▨	▨	▨	▨	
140					▨
160	▨	▨	▨	▨	
180					
200	▨	▨	▨		
220					
240	▨	▨	▨	▨	

Note. AVAS = Appetitive Visual Analogue Scale, PANAS = Positive Affect Negative Affective, EBA = , Valence = Valence Scale, Lunch = Time which participants are given sandwiches.

3.2.5. Data analysis

Data were organised into three matrices to assess: variation of each dependent variable at each measurement point; changes from baseline (T1), and changes over each successive interval (Tn:Tn+1). Data were checked for outliers with responses falling outside k=2.2, as recommended by Hoaglin and Iglewicz (1987). Skewedness was corrected using $\log_{10}$ transformations. ANOVA was used to analyse temporal trends in data for AVAS, PANAS and valence, and for EBA accuracy and reaction times with distractor type as the between-subjects factor and test session as the within-groups factor. *Post hoc* analysis was conducted using the Student's procedure. Data spread was analysed further using regression model checking and analysis of variance procedures; Pearson's correlation coefficient was also applied to data to assess covariance between the different variables. Data analysis was conducted with R, using the RStudio software package.

3.3. Results

3.3.1. Appetite

Appetite ratings across the four-hour test period followed a clear pattern of typical pre- and post-prandial changes (F (6,196) = 25.88, $p < 0.001$, $\eta_p^2 = 0.44$). Specifically, participants arrived at the laboratory with low to moderate levels of eating motivation: the mean baseline AVAS score (mean ± SD) was 150.38 ± 83.16, on a 0 - 400 scale. Subsequently, appetite levels rose incrementally at each successive pre-prandial measurement point, to reach a maximum (257.62 ± 78.41) immediately before the presentation of the lunch (F(3,112) = 8.18, adj $R^2 = 0.16$, $p < .001$). After satiating on their ad libitum meal, participants displayed the anticipated reduction in motivation to eat, so that appetite ratings (60.21 ± 64.32) were significantly lower than before (257.62.21 ± 78.38) lunch (t(29)= 11.63, $p < .001$, r= .91). This state of relative satiety persisted into the second hour after lunch, with only a gradual rise in appetite levels across the remainder of the experiment (F(2, 84) = 0.01, adj $R^2 = 0.07$, $p = 0.02$), and motivation to eat being consistently rated lower than the initial baseline (T1).

3.3.2. EBA performance

The primary attentional variable in the study was the accuracy of target detection (percentage of correct trials) at each test interval for RSVP streams containing the four different distractor types.

3.3.3. Lag-2 accuracy

Figure 3.3.1 summarizes the changes in response accuracy over time for each distractor type with a 2-lag distractor-target delay. Preliminary analysis, and visual inspection of the data, indicate a clear distinction between accuracy levels, across the whole test period, that was dependent upon the type of distractor ($F(3,784) = 29.8$, $p<0.001$, $\eta_p^2 = 0.1$). Further analyses were conducted to assess variation in response accuracy according to the specific type of food distractor at each successive replication of the EBA. Initially, we assessed changes in accuracy across T2 through T4, relative to baseline (T2) measures. Accuracy for trials with neutral distractors was initially high, and remained relatively constant across the whole experiment. In contrast, irrespective of their specific category, food distractors consistently reduced participants' ability to identify the targets.

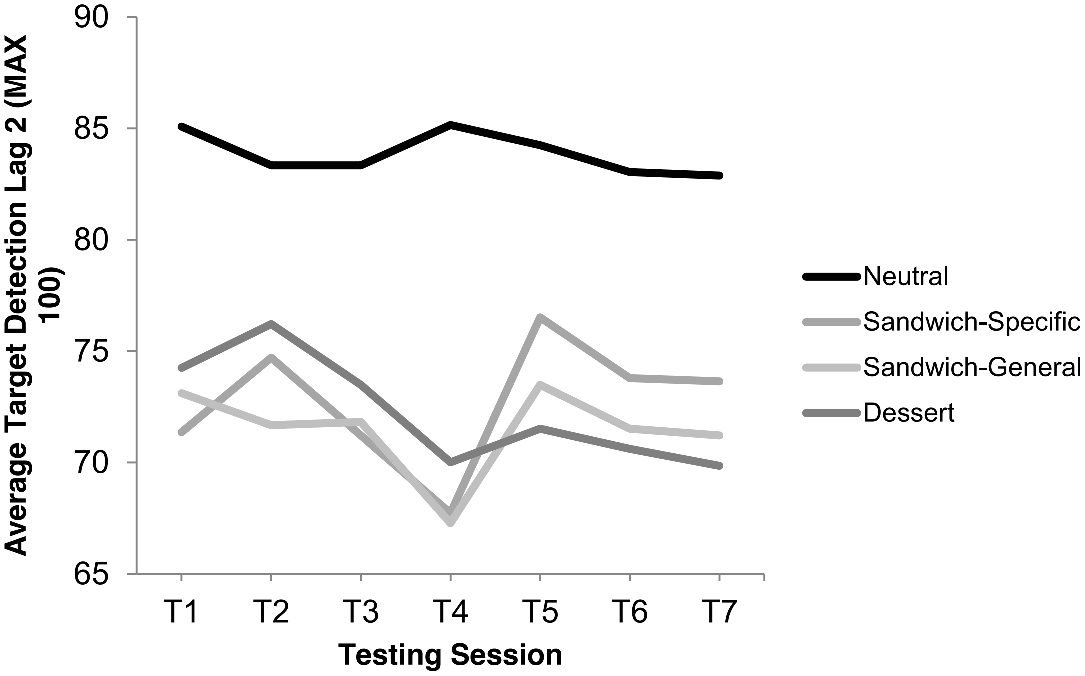


Figure 3.3.1: Pre-prandial lag-2 target detection accuracy T1-T4.

Note. T4 = pre-prandial testing session, T5 = post-prandial testing session. Notably, in the pre-prandial period, there was a general decline in accuracy for all of the food distractor categories – particularly evident between T2 and T4 ($F(15,336) = 4.54$, $R^2 = 0.10$, $p<0.001$).

Table 3.3.1. Multiple-Regression of change in target detection over pre-prandial testing sessions (T2-T4).

Variable	*B*	*SE B*	β	t-value
Neutral ntercept)	-76.29	3.1		29.64**
Sandwich-specific	-8.76	4.39	-5.45	-1.96*
Sandwich-general	-10.27	4.39	-5.97	-2.93*
Dessert	-4.53	4.39	-4.80	-1.72*
R^2		0.10		
F for change in R^2		4.54**		

Note: $*p < .05$. $**p < .001$

The lowest accuracy levels for food images (indicating the greatest attentional capture) occurred in the last EBA session before lunch (T4). These subtractive comparisons revealed a significant reductions in attention to food across the pre-prandial period (see table 3.3.1.).The accentuation of pre-prandial attentional bias to food thus closely matched the rise in motivation to eat over the same period, with all food stimuli being maximally distracting when the participants were most hungry.

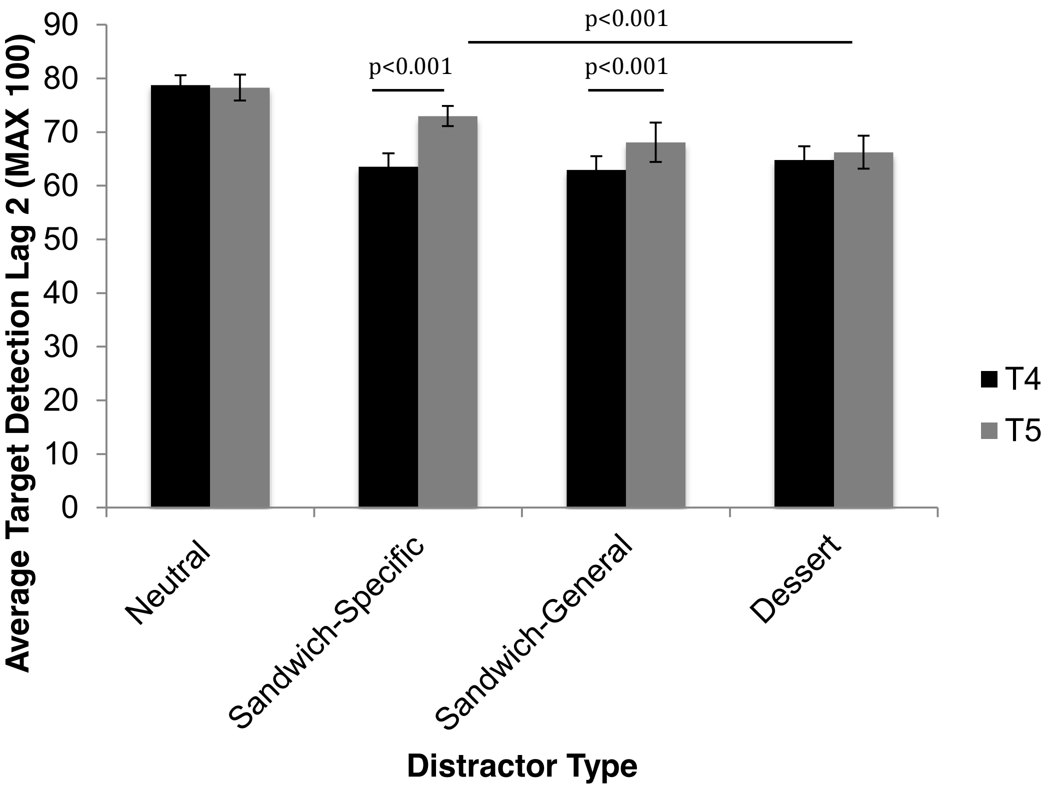


Figure 3.3.2: EBA lag-2 target detection accuracy pre-and post-prandial.

After lunch, when participants were sated, there was a very distinctive pattern of responding, with accuracy being dependent on the specific content of the food distractors. Notably, attentional capture by sandwich-specific distractors (i.e., those depicting the actual sandwich type that had been eaten) was markedly less at T5 than before lunch. Subsequently, accuracy for sandwich-specific distractors at T6 and T7 returned to the levels seen in the early pre-prandial period (T2/T3). A smaller post-lunch improvement in accuracy was observed for sandwich-general distractors, with the percentage of correct trials at T5 returning to the level observed from T1 - T3, and stabilising at that level for the remainder of the experiment. In contrast to the changes noted for sandwich distractors, accuracy for dessert distractors showed no post-lunch improvement, but rather remained at the pre-prandial (T4) level until the end of testing.

Specific comparisons between response accuracy immediately before (T4) or after lunch (T5), when the respective maximum and minimum levels of eating motivation were recorded, confirm the varied influence of different distractor types (F(3,224) = 11.02, $p<0.001$, $\eta_p^2 = 0.13$) changing with time (F(1,224 = 4.42, p=0.04, $\eta_p^2 = 0.02$). Before the meal, when participants were most hungry, each category of food distractor was similarly distracting (F=(3,112) = 9.86, $p<0.001$, $\eta_p^2 = 0.21$): accuracy levels for all food distractors were reliably lower than for the neutral distractors (p <0.001) in each case), but there was no difference in attentional bias between streams containing the different food categories (p >0.95). By contrast, when participants were sated, response accuracy altered differentially according to the type of food distractor. Compared to pre-lunch measures, accuracy was significantly improved for both sandwich-general (t(28) = 1.8, p<0.001, r = 0.32) and, more particularly, sandwich-specific (t(28) = 3.82, p<0.001 r = 0.59) distractor streams. Consequently, at T5 accuracy levels for sandwich-specific and sandwich-general distractor streams were no longer reliably lower than for neutral distractor streams (p = 0.55, p = 0.6, respectively). Dessert distractors, however, did retain their pre-prandial distracting potency when participants were satiated, and accuracy for these streams remained significantly lower than for those with neutral distractors (p = 0.02).

Further analysis of changes in accuracy across successive intervals (Tn+1:Tn) indicated clear temporal variation (F(6,784) = 4.2, p<0.001, $\eta_p^2 = 0.03$) that could be linked to appetite level and specific food distractor category. Thus, the sequential fluctuation in attentional capture was found to be closely correlated to changes in levels of eating motivation (AVAS) for sandwich-specific (r(27)=-0.43, p<0.001), but not for sandwich-general distractor streams (r(27)=-0.04, p=0.80).

Finally, examination of the size of changes in accuracy from T4 to T5 for each distractor type confirms the marked reduction in attentional capture by sandwich-depicting distractors (F(3,112)=3.17, p=0.03, η_p^2= 0.08) and, furthermore, indicates that this effect was more pronounced for distractors that specifically illustrated the kind of sandwich that had been eaten at lunch. Accuracy for neither neutral nor dessert distractors showed any appreciable change from T4 to T5 (-0.7% and 3%, respectively). By contrast, for sandwich-specific streams there was a marked 20% increase in correct responses ((t(28) = 2.9, p<0.01, r = 0.48), compared to neutral), while a more modest average increase of 11% was observed for sandwich-general streams which, however, did not differ reliably from the changes for the other stream categories.

3.3.4. Lag-4 accuracy

Analysis of 4-lag data again revealed significant main effects of distractor type (F(3,784) = 6.02, p = 0.02, η_p^2= 0.02), but without effects for time (F(6,784) = 1.43, p=0.20, η_p^2= 0.01), or an interaction (F(18,784) = 0.65, p=0.86, η_p^2= 0.01). Some aspects of the distractor- and time-related effects were similar to those noted above. For example, accuracy was generally higher for neutral distractors than for food distractors in the pre-prandial period, but greater variability in the data meant that no clear-cut pattern of change, or distinction between distractor types, was apparent post-prandially. Additionally, there was no clear relationship between accuracy and appetite level. At T4, there was a distinction between neutral and food distractors (F(3,112) = 3.18, p = .03, η_p^2 = 0.08); most notably, accuracy was reduced for sandwich-specific streams (p = 0.03) and a trend for reduced performance under sandwich-general distractors (p= 0.08). But, with the possible exception of sandwich-specific streams, there was no orderly trend for a general increase in attentional capture by food as appetite increased over the pre-lunch period. After eating, at T5, there was no longer any reliable difference between distractor types (F(3,112) = 1.4, p = .25, η_p^2= 0.03). Moreover, satiation was not accompanied by any marked degree, or consistent direction of change in lag 4 accuracy (F(3,112) = 1.13, p = .34, η_p^2= 0.03): sandwich-specific streams showed a small, non-significant increase in performance (mean ± SE = 8.4 ± 6.3%); while accuracy levels for neutral (-3.6 ± 5.0%), sandwich-general (-1.3 ± 7.4%) and dessert (2.02 ± 5.1%) streams showed no change. The general lack of consistent effects in the 4-lag data is in line with an interpretation that the distractors successfully create an attentional blink at lag 2, but not at lag 4.

3.3.5. *Reaction time*

Analysis of reaction times for 2-lag streams (Fig 3.3.3) revealed a significant effect of time (F(6,784) = 34.03, $p<0.001$, η_p^2 = 0.21), but not distractor type (F(3,784) = 0.13, p = 0.94, $\eta_p^2 < 0.01$), nor any interaction (F(18,784) = 0.07, p = 1.00). Reaction times for all distractors showed a gradual reduction over T1 - T4, before stabilising; possibly reflecting a practice effect. For lag 4 streams, a similar trend for reduced reaction times over the early course of testing was apparent (F(4,784) = 30.49, $p<0.001$, η_p^2 = 0.04). However, no main effect of distractor type was determined (F(3,784) = 0.31, p=0.82, $\eta_p^2 < 0.001$).

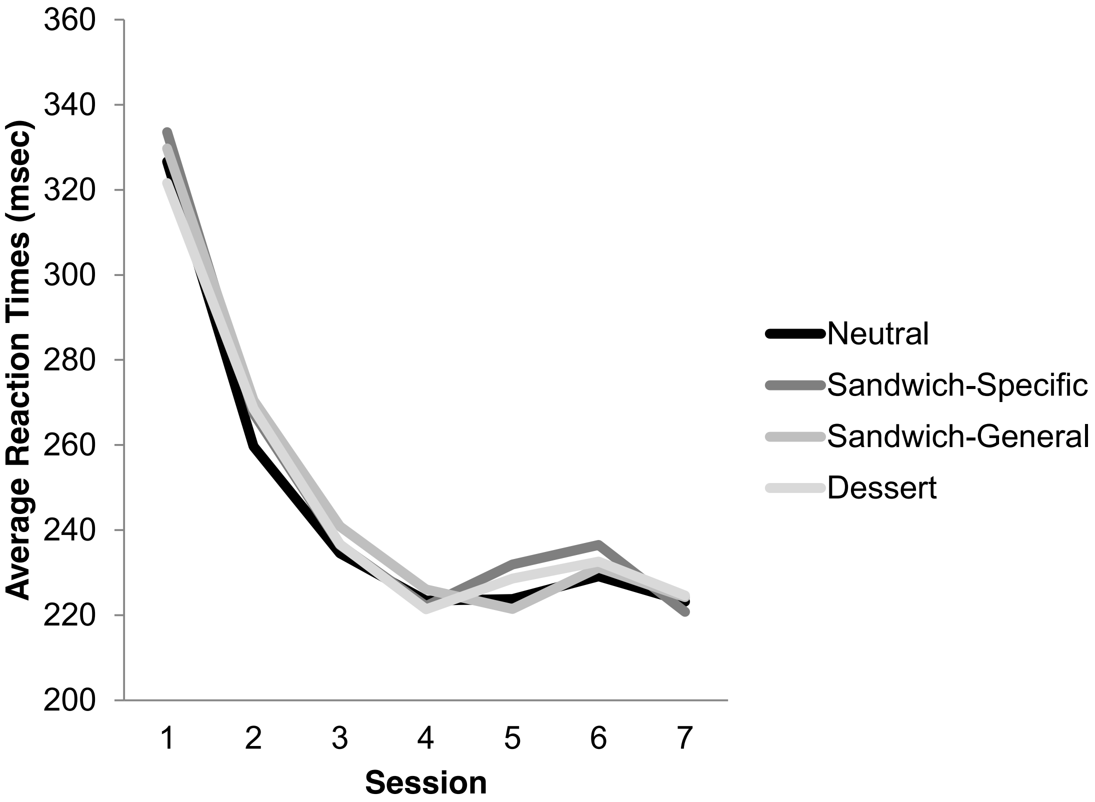


Figure 3.3.3: Average EBA reaction times across sessions

3.3.6. Valence

Examples from each image category (fillers and the four distractor types) were rated at intervals during the experiment. Valence ratings differed between image types (F (4,580) = 23.83, p < 0.001, partial $\eta^2 = 0.14$), and changes were apparent across the course of the experiment (F (3,580) = 2.88, p = 0.04, partial $\eta^2 = 0.01$), but no interaction was evident (F (12,580) = 1.21, p = 0.28, partial $\eta^2 = 0.02$). As Fig 3.3.4 illustrates, ratings for each category remained relatively constant for the neutral and dessert distractors, and the filler images. In general, desert distractors and filler images were rated more highly than neutral distractors. Initially, sandwich-specific distractor images had somewhat higher ratings than neutral distractors, but sandwich-general images received the lowest ratings – possibly reflecting the participants' lower preference for sandwiches other than the kind chosen by them for their lunch. The most notable changes evident during the experiment were respective 19% and 15% reductions in the valence of sandwich-specific and sandwich-general images following satiation, from T4 to T5 (F (4,145) = 3.86, p = 0.01, partial $\eta^2 = 0.10$).

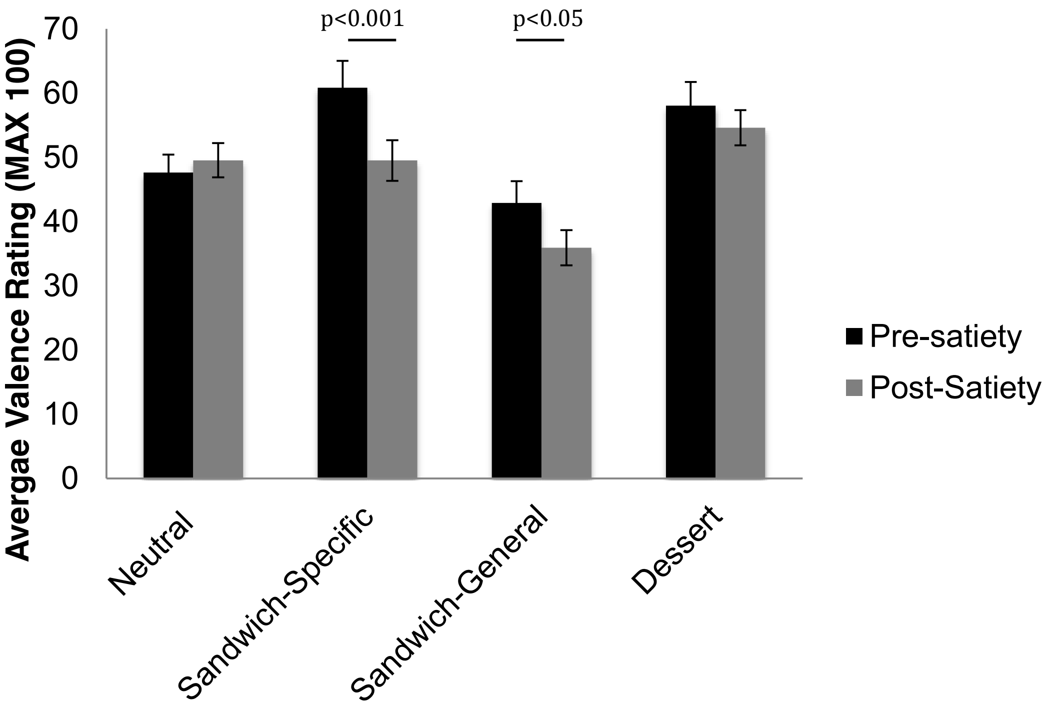


Figure 3.3.4. Pre- and post-prandial food images pleasantness ratings.

3.3.7. *Affect state*

As illustrated by Fig. 3.3.5, examination of positive affect (PPANAS) scores revealed marked changes over the course of testing (F(6,196) = 4.12, $p < 0.001$, $\eta_p^2 = 0.11$). More particularly, from a high baseline level, positive affect gradually declined over the pre-prandial period (T1 – T4), reaching a minimum before lunch (F(3,112) = 3.05, adj R^2 =0.05, p=0.03). Comparison of pre-and post-lunch measures (T4 – T5) showed a significant increase in positive affect with satiation (t(28)= 4.6, p<0.001, r=0.52). Interestingly, changes in PPANAS at each measurement interval were found to show a significant negative correlation with the corresponding changes in appetite level (r(201)=-0.49, p<0.001).

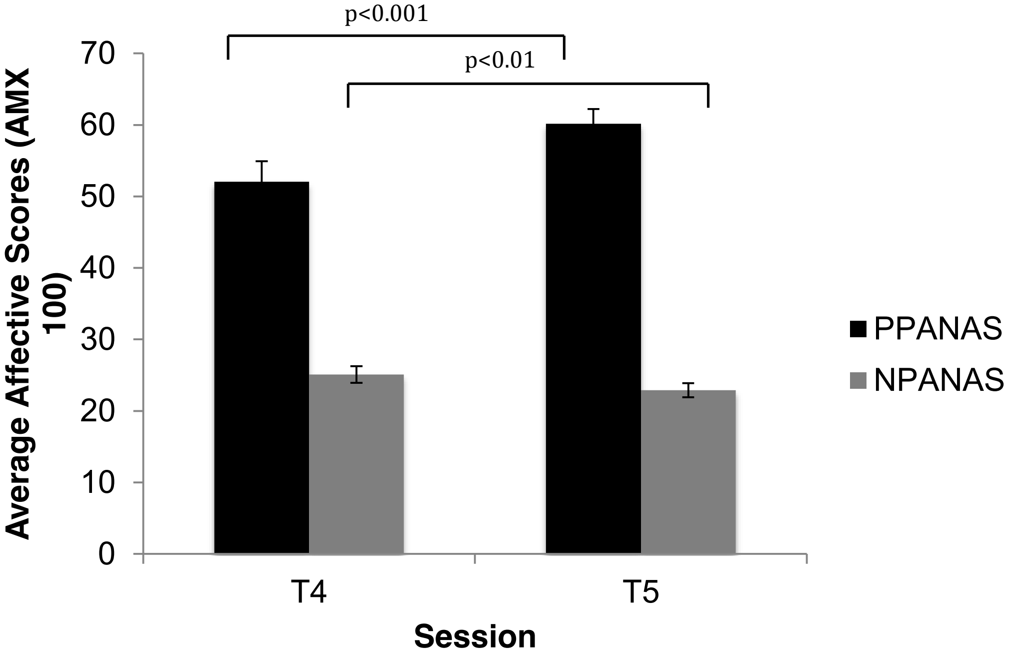


Figure 3.3.5. Pre- and post-prandial affective ratings

Adjustments to negative affect (NPANAS) scores were less pronounced, with a regression showing that initial low scores remained relatively constant across the test (F(6,196) = 1.51, p = 0.18, $\eta_p^2 = 0.04$). However, consumption of the meal led to a small, but significant reduction in negative affect between T4 and T5 (t(28)=3.00, $p<0.01$, r=0.5). Although no reliable relationship between changes in NPANAS and appetite was evident over lunch (r(201)=0.11, p=0.06).

3.4. Discussion

Implicit processing is influenced by fluctuations in motivational and affective states, with deficits in these states promoting changes in attentional processing which guide individuals towards remedies of *extremis*. These remedies are often objects of evolutionary importance that aid survival and propagation of genetic material. This study reflects the conceptualization that fluctuations in motivation influence our implicit processing of our environment. In particular, the present study demonstrates that attentional mechanisms fluctuate in line with hunger state, resulting in biased processing of food-cues when individuals were in a state of 'need', and away from food-cues following consumption of food to satiety. These findings confirm our expectations, while clearly complementing previous studies which have also found biases in the attentional processing of food-related images to be greater under a state of hunger in comparison to satiety (Castellanos et al., 2009; di Pellegrino et al., 2011; Piech et al., 2010).

3.4.1. Pre-prandial increases in attention

Considering that most organisms have evolved to satisfy their immediate needs (survival), it is hardly surprising that attention towards food-related stimuli increases when humans are hungry. Survival requires individuals to respond to both internal and external signals received from our environments and bodies. The patterns of change in implicit processing observed in the present study demonstrate this effect over the pre-prandial period with reciprocal changes between hunger and attention, with no discrimination in the relative change of attentional bias between food types. These findings may not be particularly surprising as most studies reporting a difference in attentional processing of food have required participants to fast before taking part (Channon & Hayward, 1990; Mogg et al., 1998; Piech et al., 2010; Placanica et al., 2002). However, the present data indicate that large increases in hunger motivation are not required to instigate changes in implicit processing of food. As Berridge et al. (Berridge et al., 2009) have suggested, 'wanting' of a motivational stimulus may not be consciously experienced, which may explain why explicit pleasantness ratings of food images did not change in the time leading up to consumption, while implicit measures did. It is probable that the large changes in appetite are required to influence these changes in in the hedonic value of food. Essentially, these changes in hedonic value increase the salience of non-task related food stimuli, thus reducing participants' resistance, increasing distraction by food and subsequently reducing task performance (target detection while ignoring irrelevant stimuli). The reduced ability to focus on the task, coupled with increased hunger motivation and increased salience of food, are likely to be responsible for increased responsiveness towards 'motivational objects'/food.

3.4.2. Category-specific post-prandial changes in attentional bias

Noticeable fluctuations in attentional processing of food-related images were observed pre- and post-satiety. Specifically, target detection on the EBA task for the food-type consumed (sandwiches) displayed reduced distractibility, complementing previous observations by di Pellegrino et al (di Pellegrino et al., 2011). It is unlikely that the decreased attentional processing for the consumed food was a result of extensive exposure or familiarity with the food as participants experienced equal exposure to all food types in the pre-satiation periods. Instead, it is probable that a reduction in the hedonic value of the food-type consumed occurred, resulting in changes to the salience of that food. Further support for this comes from the finding that changes in attentional processing of food-related stimuli, pre- and post-satiety, were comparable with changes in explicit ratings of image pleasantness, which displayed devaluation for sandwich-general and sandwich-specific images. This is not unexpected, as many studies have shown food-specific devaluations in subjective ratings of food liking and pleasantness following their consumption to satiety – referred to as sensory-specific satiety (Brunstrom & Mitchell, 2006; Havermans et al., 2009; E. T. Rolls & Rolls, 1997). However, the foods utilized in those studies belonged to very different, distinct categories, while the present study investigated the effects of satiation on attention to particular food images that were identical to the specific food consumed, or belonged to the same food category, but were visually distinguishable from the lunch food, or were visually and categorically distinct.

Sensory-specific satiety is described as a relative shift in the hedonic evaluation of food (Brunstrom & Mitchell, 2006). Confirming that notion, our findings revealed, in both explicit and implicit tasks that change in responsiveness to and pleasantness ratings of food images were category-specific. In other words, changes in the implicit processing of images of the consumed food category (sandwiches) after satiation were accompanied by reduced valence ratings for items within that category, while implicit processing of uneaten dessert images, which remained attractive, was unaffected.

The confirmation, here, of a relationship between attentional processing and 'pleasantness' ratings of the food consumed provides further support for the contention that changes observed in attentional processing are mediated by fluctuations in hedonic/incentive value of food stimuli, resulting from both general changes in eating motivation after satiation, and a specific reduction in the incentive value of the food-type consumed. Where a food has a particularly high intrinsic incentive value (dessert), which is unaffected by satiation, it retains its capacity to capture attention. We will explore in a subsequent experiment whether specific consumption of high-incentive dessert foods results in similar sensory-specific changes in attention to those reported above for savoury foods.

On a final note it is important to consider the role of affective processes. In the current study we found that appetitive state had a reciprocal relationship with positive affect: i.e., hunger led individuals to feel less positive, while the onset of satiety (after eating a preferred food) was associated with increased positive feelings. The role of affective processing in eating motivation is not clear-cut, with mixed reports that positive affect increases (Evers et al., 2009; 2013; Macht et al., 2002), decreases (Turner et al., 2010), or has no effect on appetite or eating (Lowe & Fisher, 1983; Yeomans & Coughlan, 2009). And yet cognitive neuroscience has consistently argued that affective processes have a fundamental role in motivation and how internalized motivations interact with the external environment (Berridge, 1996; Berridge et al., 2009; Isen & Reeve, 2006; Panksepp, 2011a; 2011b). Our findings have implications for this area of research, with a clear relationship between gradual internalized changes in motivational state (hunger) leading to changes in affect state. As hunger is often considered to cause a negative state (Birch, Fisher, & Davison, 2003; Lowe & Maycock, 1988; R. I. Stein et al., 2007), it is hardly surprising that a state of hunger leads participants to feel less positive, and for this to be alleviated following satiety. However this change in affect requires further investigation, in order to understand the role it plays in eating motivation.

3.5. Conclusion

Implicit measures provide a new and exciting way of investigating motivational processes such as hunger. In particular, they allow simultaneous investigation of both implicit and explicit systems, the interaction of which remains poorly understood with regard to hunger. Within the present experiment we have found that relationships exist between these processes. Specifically, we have seen that attentional capture by all food stimuli is enhanced as motivation to eat increases. Consuming a specific food to satiety leads to a reduction in the ability of that food to capture attention. Interestingly, our data not only indicate that attentional capture by the specific food that has been consumed was reduced after satiation, but that foods belonging to the same category, sharing many visual features also show a reduced ability to capture attention. Our data strongly suggest that our attentional systems are able to discern, and selectively filter, very specific aspects of food stimuli, adjusting responses according to whether they represent a food that has actually been eaten, similar – but different – foods, and distinctly different, unrelated foods. While suggestive of finely tuned attentional processing of food characteristics, is important to confirm these findings. However, such attentional selectivity should not be unexpected given the potential advantages of the selection of a variety of foods in optimising nutrition.

Chapter 4:

Deliciously distracting: Comparing temporal changes in attentional bias to appetising foods

4.1. Introduction

Salient motivational objects, such as food, have the ability to capture attention (Piech et al., 2010). However, the salience of these objects is thought to rely on two interacting, but distinct neural systems subserving what is often referred to as ‘wanting’ and ‘liking’ (Redish, Jensen, & Johnson, 2008; Robinson & Berridge, 2008a). The ‘liking’ system is considered to measure or assign the level of pleasure anticipated or derived from the consumption or use of an object with motivational relevance (Berridge et al., 2009). This liking system may be considered to assign baseline motivational values, while changes in the ‘wanting’ system provide alterations to this value for its relevance in real-time. For instance, a hamburger may be considered by an individual to be appetising because of previous experience. Contemporary research clearly demonstrates this, with numerous studies observing high explicit and implicit hedonic values of food in comparison to lower rated neutral stimuli of mundane objects or scenes (Brignell et al., 2010; Castellanos et al., 2009; Mogg et al., 1998; Piech et al., 2010; Werthmann et al., 2011). A variety of measurements and methodologies have found that food-related stimuli are more attractive than less interesting scenes (Lang & Bradley, 2007; Tapper, Pothos, & Lawrence, 2010), but not necessarily other objects of motivational interest, such as romantic and erotic stimuli (Piech et al., 2010). While baseline hedonic values play a crucial role in the how we respond to food, the motivation to interact/consume (‘wanting’ system) regulates the urgency to act on a motivation: i.e., food should no longer be priority once an individual has consumed lunch to satiety. Early research with studies investigating alimentary alliesthesia and sensory-specific satiety with explicit measures have demonstrated changes in the hedonic power of food pre- and post-prandially (Bell, Roe, & Rolls, 2003; see Brondel et al., 2006; Havermans, Siep, & Jansen, 2010; Olsen, Ritz, Hartvig, & Møller, 2011; Snoek, Huntjens, Van Gemert, de Graaf, & Weenen, 2004), along with the aforementioned implicit studies. This research, including our own (see Chapter 3), has gone further to show that attentional biases in the implicit processing of food fluctuate relative to appetitive state, with satiation resulting in reduced attention to food (Castellanos et al., 2009). In essence, wasting precious neurocognitive resources to focus on food when there are other evolutionary priorities to attend to is wasteful. However, this straightforward perspective of the 'wanting' and 'liking' systems oversimplifies the plethora of interactions between hedonic value and motivational relevance, with environmental context and food availability. The interactions of humans and environments complicate these exchanges, and any investigations into the interactions of appetite and motivation in general.

Complicating these factors further are research findings that the rating and processing of food goes beyond the general devaluation of food following satiation. In the last few decades a number of studies have highlighted a process known as 'sensory-specific satiety' (SSS), whereby consumption of a specific food results in the specific devaluation of that food's pleasantness, but not of foods that have not been eaten. Essentially, the fundamental principle of SSS is that the pleasantness of a specific food decreases following its consumption to satiety, relative to unconsumed foods that were rated as similarly pleasant prior to eating. Support for these principles emerged from research investigating differences in the explicit ratings of food before and after eating. Typical SSS experiments involve pre-meal tests that comprise a taste test coupled with an evaluation process for pleasantness of the sensory characteristics of a variety of foods. Following these evaluations, participants are instructed to consume just one of the foods to satiety, after which a second, post-prandial evaluation identical to the first session is conducted. Research utilising similar methodologies commonly finds devalued pleasantness ratings for the specific food consumed in comparison to pre-test ratings, while the pleasantness ratings for the unconsumed foods remain relatively unchanged (Hetherington & Rolls, 1996; E. T. Rolls, 2006). According to Bell et al (Bell et al., 2003), a fundamental factor in SSS is the volume of food consumed, which has a greater influence on SSS changes in pleasantness than energy density. For instance, Bell and colleagues (Bell et al., 2003) discovered that evaluations of pleasantness for a milk-based drink reduced were related more to the volume consumed than the number of calories. Manipulation of the calorie content of meals, using aspartame or sucrose (D. L. Miller, Bell, Pelkman, Peters, & Rolls, 2000; B. J. Rolls, Laster, & Summerfelt, 1989), had little effect on meal pleasantness, while variation in volume had a greater influence on the sensory specific effect. Essentially the studies of Rolls et al (1989), and Miller et al (2000) that consuming larger volumes of food reduced food pleasantness more than lower volumes. In addition the calorie content of the food consumed had no influence on ratings of food before and after consumption. With volume being more important than nutritional content, it appears that the physical and perceptual characteristics of food consumed would be essential in specifying satiation of a particular food. Principally it appears from explicit evaluations of food 'liking' that food consumption temporarily suppresses the hedonic value of the consumed food (see Weenen, Stafleu, & de Graaf, 2005). Although the exact mechanisms of SSS are uncertain, SSS is clearly characterised by both decreases in pleasantness/'liking', and 'wanting' (Berridge, 1996; Mela, 1999; 2001).

Investigation into changes of food pleasantness and appetitive state, particularly with regards to SSS, have provided great insight into the explicit components of these mechanisms. However, Robinson and Berridge amongst others have stated that 'liking' and 'wanting' reflect fundamental processes of motivation which can operate independently of conscious awareness (Berridge et al., 2009; Berridge & Robinson, 2003; Finlayson et al., 2007). Understanding the components of motivation operating at both explicit and implicit levels that influence eating behaviour is essential to fully understand the processes involved in food selection and consumption (Finlayson, King, & Blundell, 2008). And understanding implicit processes may provide further insight into the factors influencing SSS. The crucial factor is that while explicit measures tap into conscious attitudes (e.g., subjective ratings (e.g. Brunstrom & Mitchell, 2006; Weijzen et al., 2008), most individuals do not consciously analyse their attitudes towards stimuli. Instead, behaviour is both energised by motivational systems and guided by spontaneous interactions with the environment (Griffioen-Roose et al., 2010). To gauge these spontaneous responses to motivational stimuli, implicit measures, such as dot-probe and the emotional blink of attention (EBA) tasks have been developed. These methods are thought to detect changes in implicit processing as a result of changes in motivational relevance/'wanting', that influence real time hedonic values/'liking', and in turn affect the salience of motivational objects, such as food (Berridge, 1996; Berridge & Kringelbach, 2015).

A previous study we conducted (See chapter 3) found selective reductions in attention to images of the specific food type that was consumed to satiety, reflecting other studies demonstrating sensory specific phenomena within implicit systems (di Pellegrino et al., 2011). Our findings also imply that the cognitive effects of satiety on implicit processes are not restricted to sensory-specific (food-specific) features but also suggest a category-specific effect. Thus, after eating a particular type of sandwich attentional bias was reduced for images of that item and, to a lesser extent, images of sandwiches with fillings discernibly different from the one that has been consumed. Therefore, satiation reduces attention not only to the satiating food but also to foods within the same category that share common features. Interestingly, this categorical shift reflects a study by Rolls, VanduijVenoorde, and Rolls (B. J. Rolls, Van Duijvenvoorde, & Rolls, 1984) who found that unconsumed

foods that share the sensory characteristics of eaten foods also decline in pleasantness relative to foods with different properties.
Importantly, in our earlier experiment, attention to images of non-consumed, highly palatable dessert foods was unaffected by postprandial changes in appetite: attentional capture by these items was consistently high across the whole experiment. This raises the question as to whether the lack of change for desserts reflects a sensory-specific outcome, or the specific property of desserts as high incentive value stimuli. In other words, dessert images may have been resistant to satiation induced changes in attention because they belong to a different food category, or because their intrinsic incentive salience renders them immune to a satiation-related decline in the general motivation to eat and incentive value of less desirable foods.

Importantly the findings of our study were relative to a non-consumed food type (desserts), which continued to capture attentional processes regardless of appetitive state (remaining high even after satiation). This reflected findings elsewhere on the implicit processing of food-related stimuli (di Pellegrino et al., 2011). These findings in concordance with present literature imply that highly incentivised stimuli are able to override the influence appetitive state (Lutter & Nestler, 2009; I. Nijs, 2010). This presents a novel question: will attentional processing of highly palatable foods follow the predictions of incentive salience (Berridge et al., 2009) or SSS if individuals consume highly palatable, and therefore hedonic, foods to satiety?

Understanding if the same responses occur for savoury and predominantly sweet dessert foods is vital as the majority of food that humans consume may be categorised as either sweet or savoury, with almost 90% of food falling into these categories (Mattes, 1985). Understanding the differences between attentional responses to these food categories in the context of changing eating motivation with consumption may help us understand why individuals consume foods which are not required nutritionally or to their long-term benefit.

Currently research of explicit pleasantness ratings has shown that ratings of savoury meals fluctuate in line with appetite, while ratings of sweet foods follow very different patterns over long periods, being stable across time (de Graaf et al., 1993). Specifically, pleasantness ratings of both sweet and savoury foods follow typical SSS reductions after consumption (de Graaf, Jas, Van der Kooy, & Leenen, 1993). Currently, we would expect changes in the implicit processing of food to comply with the incentive salience theory with regard to appetite level and relative to the food consumed. However, until now, no attempt appears to have been made to track changes in attentional responses to highly appetising stimuli in relation to naturalistic changes in hunger, and consumption of those foods. While very few studies have investigated attentional processing of foods based on their sensory/hedonic characteristics in relation to consumption and appetite.

The present study investigated if the apparent appetite-independent ability of highly palatable dessert stimuli to capture attention remains after actual consumption of such foods, or whether highly palatable foods can also induce sensory-specific changes in attention. In the following experiment, we applied the EBA method to assess sensory-specific changes in the implicit processing of two kinds of highly palatable, sweet foods: cheesecake and fruit.

4.2. Experiment 1

4.2.1. Method

4.2.1.1. Participants

Twenty-eight normal weight participants (13 males, 15 females; BMI =

22.19 ± 1.34) aged between 18 and 40 years (mean age = 24.25 ± 5.13) with normal-to-corrected vision were recruited from the staff and student population at the University of Liverpool using opportunity-sampling methods. Participants were required to be non-smokers, non-dieters and habitual lunch eaters, and to enjoy eating cheesecake. Exclusion criteria included food intolerances or allergies, or current use of any medication influencing appetite or attention. Participants were informed that the study was investigating changes in attention to motivationally significant stimuli over time, in relation to fluctuating motivational state; however no specific reference was made to our central focus of changes in attention towards specific food types relative to appetitive state. Participants were financially compensated for their participation in experiment. The University of Liverpool's Institute of Psychology, Health and Society Ethics Committee gave ethical approval for the study.

4.2.1.2. Emotional Blink of Attention Task

The study utilized an adapted version of the emotional blink of attention (EBA) paradigm (see Piech et al., 2010). The EBA task consisted of several trials within which the participant was required to detect a target amongst a series of images presented within a rapid visual stream, presented on a laptop using E-Prime 2.0.242. Each trial (visual stream), comprised of 17 images presented consecutively, serving one of three functions: filler, distractor, or target (see Fig 4.2.1). Each image in the stream was displayed for 100ms, with no interval in the presentation of the successive images. Distractor (neutral or food) images could appear randomly at any point within the visual stream after the three initial filler (landscape) images had been displayed. In the present experiment distractors may be: neutral, cheesecake-specific, cheesecake-general, sandwiches or fruit. Target images (landscape images rotated 90° degrees either clockwise or counter-clockwise) were displayed 200 ms after the onset of the distractor (2-lag). At the conclusion of each stream participants were required to indicate, by key press in response to screen prompts, whether they had seen the target and, the orientation of the image to the left or right. Participants were instructed to answer as quickly as possible. Only trials for which the participant reported seeing the target and correctly indicated its rotation were taken as correct responses. The program recorded reaction times to the questions, and the key responses.

On each testing session, participants were exposed to 4 blocks of 50 streams (trials), with a 30-second interval between successive blocks. The different distractor categories were distributed randomly and equally across the four blocks. All images were taken from their respective image banks randomly.

Figure 4.2.1. Diagram of EBA stream with distractor options relative to cheesecake meal

4.2.1.3. Visual stimuli

A total of 854 colour, luminance-matched, photographic images were used, each presented on screen in a 95 mm wide x 75 mm high format, viewed at a distance of approximately 500 mm. Images were taken from the

International Affective Picture System (IAPS) databank (Lang et al., 2008) , supplemented by photographs of food prepared specifically for this study. The fillers were selected from 252 images of landscapes and urban scenes. The targets were drawn from separate banks of similar scenes rotated either 90° to the left (136) or right (135). Neutral distractors were 48 images selected from the IAPS, depicting commonplace objects or scenes and chosen for their low arousal and neutral valence ratings.

Food distractors belonged to one of four categories: cheesecake-specific, cheesecake-general, fruit, or sandwiches. Fifty cheesecake-specific images represented the particular cheesecake type (cheesecake-specific) that each participant had selected to eat for their lunch, taken from a range of different perspectives with the filling being easily identifiable in each. Cheesecake-general distractors were drawn from 100 equivalent photographs representing 2 other cheesecake-types. Sandwich distractors were selected from 90 photographs of sandwiches, while fruit distractors were selected from 158 images of three different types of fruit: strawberries, melon, and grapes matched to the background and luminosity of the cheesecake images.

4.2.1.4. Procedure

Participants arrived at the laboratory at 10:50 for preliminary screening to ensure compliance with inclusion and exclusion criteria, and to complete the informed consent procedure. No specific instructions about eating were given before the study, other than to indicate that participants should not bring food to the laboratory as a cheesecake meal was to be provided. During recruitment, participants were informed that they would be provided with as much cheesecake as they might want to eat during the experiment. Prior to the test session, participants were asked to select their preferred cheesecake from a choice of three commonly available choices: vanilla, strawberry or chocolate. Cheesecakes were obtained from a national supermarket chain (Tesco. see table 4.2.1 for energy and macronutrient content).

Table 4.2.1. Cheesecake energy and macronutrient content

Cheesecake	Kcal	Fat	Saturates	Sugar	Salt
Vanilla	364	24.7	15.2	22.6	0.4
Chocolate	430	29.1	17.4	29.8	0.2
Strawberry	336	19.4	11.5	23.6	0.4

Note. Nutrient content refers to one slice of cheesecake. Participants were served two slices.

Participants were required to remain within the laboratory for the duration of the experiment, but during the intervals between testing sessions, they were allowed to relax in a lounge area where they had access to computers and the internet, along with a range of reading material and a television.

Initially, participants completed the Positive Affect Negative Affect Scale (PANAS) (Watson et al., 1988) and an appetite visual analogue scale (AVAS; adapted from Blundell et al, 2010). The PANAS requires participants to indicate the extent to which each of 20 different affective terms explain how they feel, rated on a 5-item Likert scale, anchored by ‘Not at all’ and ‘Extremely’. The AVAS comprises 4 appetite-related items (‘How hungry do you feel?’, ‘How strong is your desire to eat?’, ‘How full are you’, and ‘How much food do you think you could eat’), and 8 questions recording levels of general motivation. The questionnaire utilised a 100 mm VAS to record responses to each item, anchored with the terms ‘Not at all’ and ‘Extremely’. A single AVAS score was derived from the sum of ratings on the 4 appetite items, with a potential maximum score of 400 indicating the highest level of motivation to eat. Additionally, participants completed a valence task in which they were asked to rate the attractiveness of 10 images selected from each of the following categories: landscape, neutral, cheesecake-specific, cheesecake-general, fruit, and sandwiches. The images were rated on a 100 mm visual analogue scale, anchored with the terms “not at all attractive” and “extremely attractive”.

Having completed these initial ratings, participants undertook the first EBA session. Subsequently, over the course of 3 hours, the AVAS, PANAS and EBA were repeated on 4 occasions, each separated by a 40-minute interval. One hundred minutes after the start of testing (at approximately 12:40), participants were given lunch, comprising their preferred, pre-selected cheesecake and water to drink. Each participant was provided with 4 identical slices of cheesecake (weight of each slice = 180g), presented on a x cm diameter plate, and were invited to eat as much, or as little, as they wanted.

Testing recommenced 20 minutes later, as described above. Both before and after lunch, and again after the final test session, participants repeated the valence test to rate the attractiveness of the images originally shown to them at the beginning of the experiment.

Finally, the participants were asked to respond to the dutch-eating behaviour questionnaire (DEBQ) (van Strien et al., 1986). The TFEQ was administered to provide a trait-based measure of eating behaviour. The questionnaire had three subscales: cognitive restraint (extent to which an individual controls and restrains food consumption); disinhibition (vulnerability of control of consumption to disruption), and susceptibility to hunger (an individual’s sensitivity to awareness of hunger). The DEBQ consisted of 33 items that assess three subscales: external eating (10 items; responsiveness to the exposure of food-related stimuli), emotional eating (13 items; assessing food consumption in response to emotion), and dietary restraint (10 items; assessing restrict food intake). Items in the DEBQ utilized Likert 5-point scales measuring how frequency each item was applicable to (1 = never; 5 = very often). Items referred to components the food consumption traits: Emotional, Restrained and External eating. At the conclusion of the experiment participants were thoroughly debriefed. See table 4.2.2 for order of testing.

Table 4.2.2. Schedule of testing

Time (min)	**PANAS**	**AVAS**	**EBA**	**Valence**	**Lunch**
0	■	■	■		
20					
40	■	■	■		
60					
80	■	■	■	■	
100					■
120	■	■	■	■	

AVAS = Appetitive Visual Analogue Scale, PANAS = Positive Affect Negative Affective, EBA = Emotional Blink of Attention, Valence = Valence Scale, Lunch = Time which participants are given food. Grey = Tested in time period.

4.2.1.5. *Data analysis*

Data were organised into three matrices to assess: variation of each dependent variable at each measurement point; average score, changes from baseline (T1), and changes over each successive interval (Tn…Tn+1). Data were checked for outliers with responses falling outside *k*=2.2 (see Hoaglin

& Iglewicz, 1987). Skewedness was not corrected, as descriptive statistics did not display any violations of parametric assumptions. Analysis of variance (ANOVA) techniques were applied to temporal analysis of data trends in AVAS, PANAS, valence, EBA accuracy (%) and reaction times. Within these analysis distractor type, and gender were used as between-subjects factors, while test session (Tn) acted as within-groups factor. *Post hoc* analysis was conducted using Tukey HSD procedures. Regression models were also utilised to investigate spread and direction of data. And finally Pearson's correlation coefficient were utilised to compare covariance between different variable e.g. attention accuracy and appetitive state. Data analysis was conducted with R, using the RStudio software package.

4.2.2. Results

Participants were recruited with the same criteria used for experiment 1, through the University of Liverpool's announcement system. Twenty-seven (13 males, 15 females) normal weight participants (BMI: females = 23.8 ± 1.23; males = 22.84 ± 0.76) aged between 18 and 40 years (males = 24.77 ± 1.57; females = 21.67 ± 0.65) took part.

4.2.2.1. Appetite

Appetite ratings across the course of the experiment closely resembled characteristic patterns of pre- and post- prandial change ($F(3,108) = 84.52$, $p < 0.001$, $\eta_p^2 = 0.70$). In particular, participants arrived for testing with low or moderate levels of hunger: mean (± SD) = 51.18 ± 16.12, on a 0 - 100 scale. Levels of eating motivation rose incrementally from baseline to a maximum (71.18 ± 11.93) pre-prandial rating ($F(3,108) = 13.34$, adj $R^2 = 0.23$, $p < .001$) prior to the cheesecake meal. Following consumption of cheesecake, participants reported much reduced appetite (15.59 ± 12.37) in comparison to the pre-prandial level ($t(27) = 16.63$, $p < .001$, $r = .95$). On average participants consumed 235.69 ± 78.53 g of cheesecake, equating to mean energy intake of 783.02 ± 270.28 kcal), with no significant sex difference for either the weight of food or energy consumed ($t(25) = 1.69$, $p = .1$, $r= .32$; $t(25) = 1.73$, $p = .1$, $r= .33$, respectively).

4.2.2.2. EBA performance

The primary measure of attention in the study was the accuracy of target detection (% of correct trials) for RSVP streams under the five different distractor conditions: neutral, cheesecake-specific, cheesecake-general, sandwiches, and fruit.

4.2.2.3. EBA Accuracy

An initial analysis of changes in response accuracy for each distractor type across the course of the experiment indicated a clear distinction between accuracy levels over the course of the experiment ($F\ (3,540) = 11.41$, $p < 0.001$, $\eta_p^2 < 0.001$). However, this effect was strongly influenced by an intial practice effect between T1 and T2, as seen in previous experiments. Consequently,T2 was utilised as the baseline measure for further analysis of response accuracy. An ANOVA analysis of response accuracy from T2 indicated distinct differences in target detection accuracy between distractor types ($F\ (4,405) = 5.36$, $p < 0.001$, $\eta_p^2 = 0.05$), but no effect of time ($F\ (2,405) = 0.12$, $p = 0.89$, $\eta_p^2 < 0.001$) and no distractor x time interaction ($F(8,405) = 0.14$, $p = 0.99$, $\eta_p^2 < 0.001$).

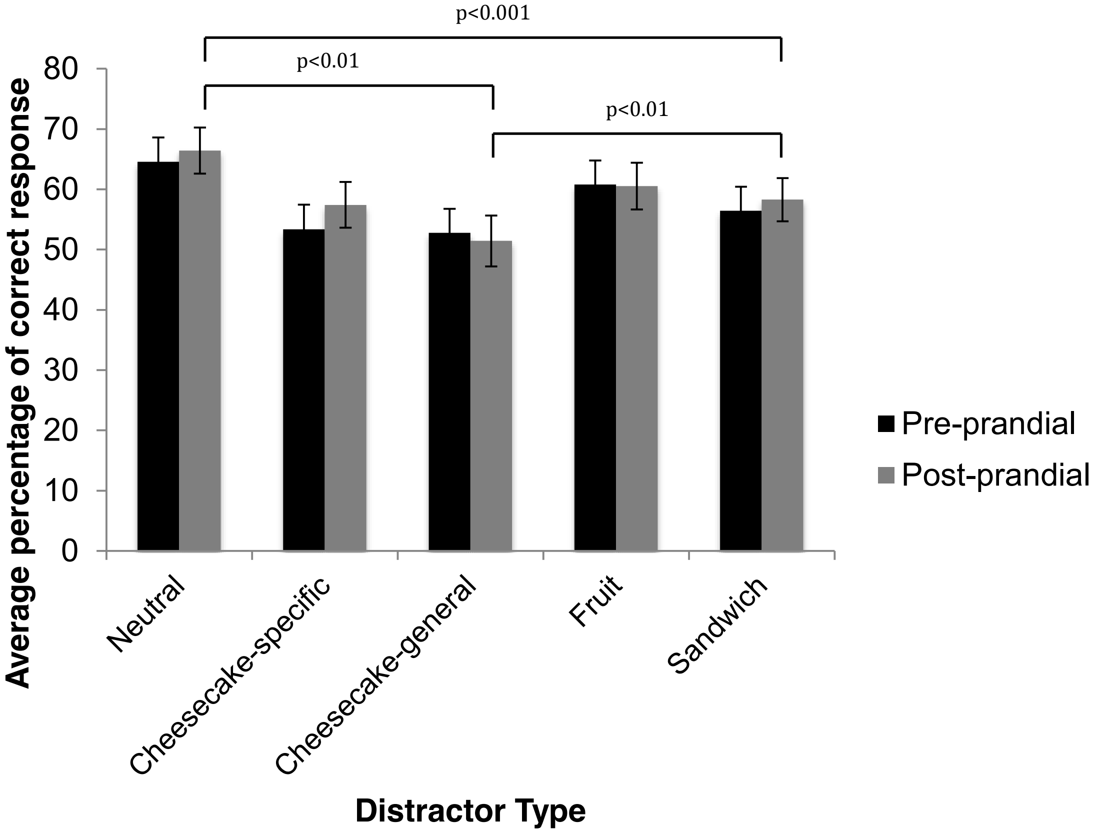


Figure 4.2.2. Average EBA target detection accuracy pre- and post-prandial

Despite a progressive increase in appetite, no change in the accuracy of target detection was observed in the T2-T3 pre-prandial period ($F(9,270) = 1.64$, $R^2=0.05$, $p=0.1$). There were, however, some differences in the separation of accuracy measures for the different distractors apparent between T3 and T4 ($F(4,270)= 3.37$, $p=0.01$, $\eta_p^2= 0.05$) (see Tables 4.3.1 and 4.3.2). Before the meal (T3) all distractor categories, with the exception of fruit, produced significant reductions in response accuracy compared to neutral distractors (Table 4.2.3), with cheesecake images producing the greatest deficit. Cheesecake and sandwich images were also significantly more distracting than images of fruit. However after cheesecake consumption (T4), displayed similar levels of distraction were found for all food distractors, and were therefore, not reliably influence by consumption ($F(1,270)= 0.24$, $p=0.62$, $\eta_p^2< 0.001$).

Table 4.2.3. Pre-prandial (T3) target detection accuracy by distractor type (% correct responses)

		Mean ± SD		Statistics	
Distractor 1	Distractor 2	Distractor 1	Distractor 2	t-value	*p-value*
Neutral	CC Specific	64.55 (21.31)	53.39 (21.59)	4.43	<0.001
Neutral	CC General	64.55 (21.31)	52.77 (21.27)	3.74	<0.001
Neutral	Sandwich	64.55 (21.31)	56.43 (21.28)	2.75	0.01
Neutral	Fruit	64.55 (21.31)	60.80 (21.19)	1.37	0.18
CC Specific	CC General	53.39 (21.59)	52.77 (21.27)	0.25	0.81
CC Specific	Sandwich	53.39 (21.59)	56.43 (21.28)	-1.16	0.25
CC Specific	Fruit	53.39 (21.59)	60.80 (21.19)	-3.4	<0.01
CC General	Sandwich	52.77 (21.27)	56.43 (21.28)	-1.78	0.09
CC General	Fruit	52.77 (21.27)	60.80 (21.19)	-3.33	<0.01
Sandwich	Fruit	56.43 (21.28)	60.80 (21.19)	-2.07	0.04

Note. CC=Cheesecake

Table 4.2.4. Post-prandial (T4) target detection accuracy by distractor type (% correct responses)

		Mean ±SD		Statistics	
Distractor 1	Distractor 2	Distractor 1	Distractor 2	t-value	*p-value*
Neutral	CC Specific	66.43 (20.18)	57.41 (20.10)	3.71	<0.001
Neutral	CC General	66.43 (20.18)	51.43 (22.35)	5.55	<0.001
Neutral	Sandwich	66.43 (20.18)	58.30 (18.97)	3.05	<0.01
Neutral	Fruit	66.43 (20.18)	60.54 (20.59)	2.79	<0.01
CC Specific	CC General	57.41 (20.10)	51.43 (22.35)	2.33	0.03
CC Specific	Sandwich	57.41 (20.10)	58.30 (18.97)	-0.4	0.69
CC Specific	Fruit	57.41 (20.10)	60.54 (20.59)	-2.1	0.04
CC General	Sandwich	51.43 (22.35)	58.30 (18.97)	-3.18	<0.01
CC General	Fruit	51.43 (22.35)	60.54 (20.59)	-4.21	<0.001
Sandwich	Fruit	58.30 (18.97)	60.54 (20.59)	-1.26	0.22

Note. CC=Cheesecake

However, a slight increase in accuracy for cheesecake-specific streams (T3: 53.39 ± 21.59, T4: 57.41± 20.10) led to a significantly better performance for this category than for cheesecake-general distractor streams ($t(27)= 2.33$, $p<0.05$, $r = 0.41$). Additionally, performance for cheesecake-general distractors was now significantly lower than for sandwich images ($t(27)= 3.18$, $p<0.01$, $r = 0.52$).

4.2.2.4. *Reaction time*

Analysis of reaction times for the different distractor streams revealed significant effects of time ($F(4,540) = 86.3$, $p<0.001$, $\eta_p^2 = 1.0$), but not of distractor type ($F4,540) = 0.04$, $p = 1.0$, $\eta_p^2 = 0.04$), nor any interaction ($F(4,540) = 0.11$, $p=1.00$, $\eta_p^2 = 0.09$). A gradual reduction in reaction times occurred for all distractors from T1 to T3, before stabilising; possibly reflecting a practice effect.

4.2.2.5. *Affective State*

We assessed pre- and post-prandial changes in positive and negative affect (see Figure 4.2.3). An initial analysis found a trend for PPANAS scores to decline pre-prandially, falling to a minimum at T3 (52.79±13.74) before increasing after the meal ($F (3,108) =2.44$, $p = 0.07$, $\eta_p^2 = 0.06$). Comparison of scores immediately before and after the cheesecake meal revealed a marked increase in PPANAS after eating (59.06 ± 15.24; $t(27)= 3.06$, $p<0.01$, $r =.51$).

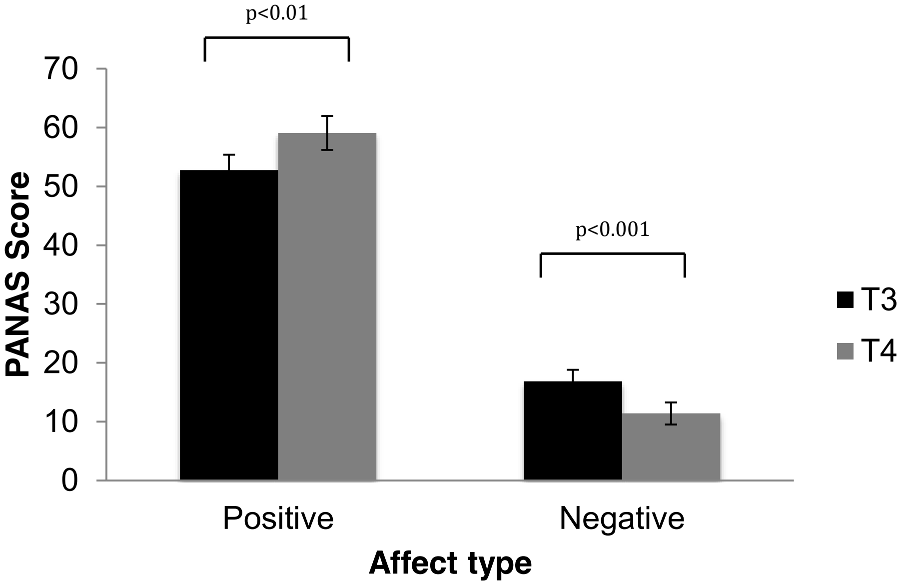


Figure 4.2.3. Pre and post- prandial affective scores

Similarly, NPANAS was found to change from T1-T4 (F (3,108) =1.72, p = 0.02, $\eta_p^2 = 0.05$), with a gradual increase in negative affect from the start (13.7 ± 9.58) of testing to a maximum (16.82 ±10.46) prior to meal consumption. After eating NPANAS (11.39 ± 10.02) was observed to fall significantly (t(27)= 4.18, $p<0.001$, r =0.63).

4.2.2.6. Valence scores

As summarised in Fig. 4.2.4, valence ratings for the different image categories differed significantly at T3, before the test meal (F (5,125) = 4.07, $p < 0.05$, $\eta_p^2 = 0.14$). Notably, pre-prandial ratings of cheesecake images were positively evaluated. After the meal, valence differences were still evident (F (5,125) = 8.64, $p < 0.001$, $\eta_p^2 = 0.26$). However, the most notable change was a reduction in the ratings of both cheesecake-specific (t(56)= 2.71, p=0.001, r =.34) and cheesecake-general images (t(56)= 3.1, $p<0.01$, r =.38).

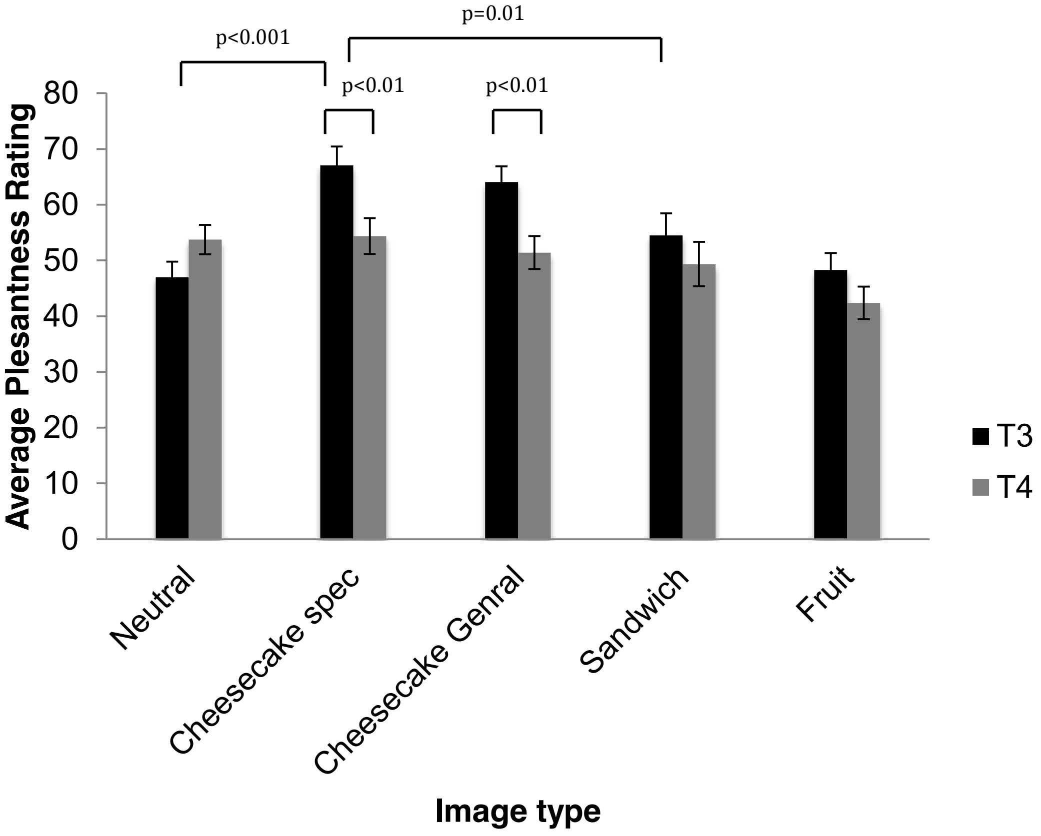


Figure 4.2.4. Average pre- and post-prandial valence scores

4.2.3. Discussion

We found that attentional capture by cheesecake images was unaffected by appetitive state, with cheesecake consumption to satiety having little or no effect on attentional processing, despite large changes in appetite. This lack of effect runs counter to our earlier finding with sandwich consumption and similar investigations by other authors assessing temporal changes in attention to food (di Pellegrino et al., 2011; Piech et al., 2010), all of which found reduced attentional processing of images of a consumed food post-prandially compared to the pre-prandial state.

Interestingly, while explicit ratings reported reductions of pleasantness for all foods., sensory-specific were evident, with changes in the pleasantness of the food category consumed (cheesecake-specific and -general) displaying the greatest decreases. It appears that there is a distinction between explicit and implicit systems with regard to highly palatable sweet foods. Implicit processing of cheesecake, and possibly other highly palatable sweet foods, may be resistant to the sensory-specific attentional changes associated with satiety observed with savoury foods.

Given the differences between the effects of sandwich and cheesecake consumption on attentional bias, further investigation of these phenomena is warranted. The following experiment was designed to assess whether sensory-specific changes in attention would follow the consumption of a another palatable, sweet food – fruit, which arguably has similar sensory characteristics to manufactured desserts but which may differ from them in terms of its incentive value and hedonicity.

4.3. Experiment 2

4.3.1. Method

4.3.1.1. Participants

Participants were recruited with the same criteria used for experiment 1, through the University of Liverpool's announcement system. Thirty-two (14 males, 19 females) normal weight participants (BMI: females = 21.08 ± 1.51; males = 21.08 ± 1.51) aged between 18 and 40 years (males = 25.64 ± 2.16; females = 22.63 ± 0.67) took part.

4.3.1.2. Procedure and materials

The general method and procedure utilised in experiment 2 was exactly the same as outlined, above, utilising the same questionnaires and testing schedule of explicit and implicit measures as Experiment 1. The only major change in the material was the food given, food was an option for one of three fruits: green grapes, strawberries, or melon. Nutrient details of fruit are provided in table 4.3.1.

Table 4.3.1 Fruit energy and macronutrient content

Cheesecake	Kcal	Fat	Saturates	Sugar	Salt
Grapes	278	0.1	<0.1	15.4	<0.01
Melon	100	0.1	0	4.7	0.1
Strawberry	128	0.1	<0.01	6.0	0.1

Note. Nutrient content refers to 100g. Participants were served 500g of grape and strawberries, 1000g of Melon (including outer skin).

4.3.1.3. EBA adaptations

However a few modifications were made to both the EBA and the food given for consumption during in the study. Food distractors belonged to one of four categories: fruit-specific, fruit-general, cheesecake or sandwich. Fifty-two fruit-specific photographic images represented the particular fruit type that each participant had selected (fruit-specific) to eat in the experiment, either strawberries, melon or grapes, with images taken from a variety of perspectives. Fruit-general distractors were drawn from 104 equivalent photographs representing the other, non-consumed fruit types. Cheesecake images used in experiment 1 made up the images of the cheesecake distractors ($n = 150$). While all other images in the EBA remained the same with the same roles.

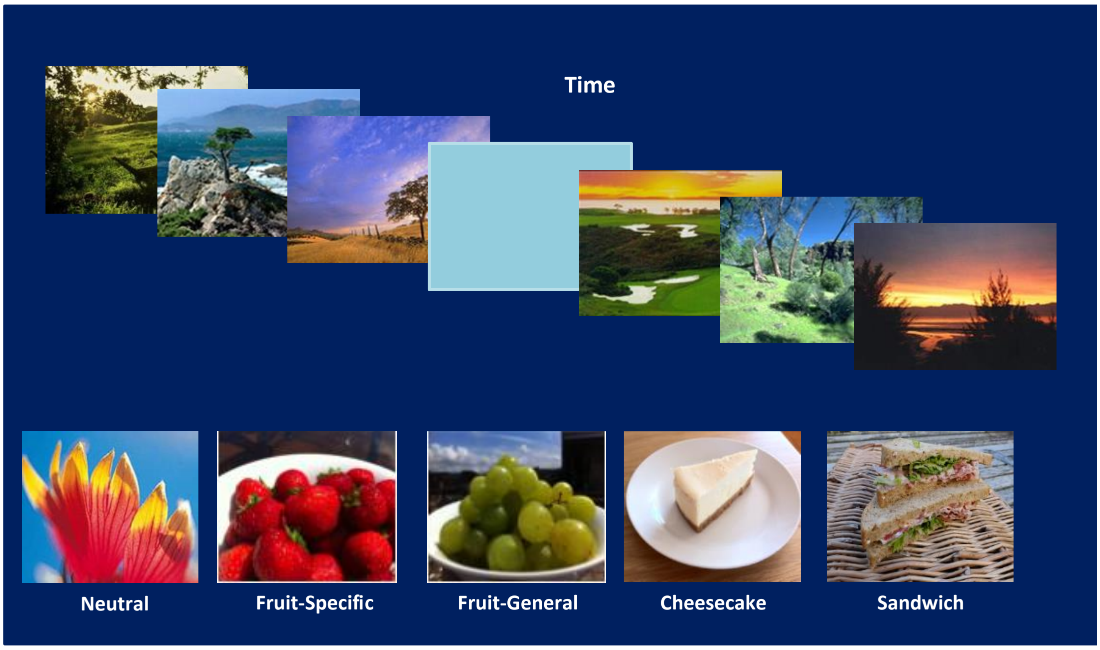


Figure 4.3.1. Diagram of Fruit EBA stream with distractor options

4.3.2. Results

Ratings of appetite displayed typical patterns of pre- and post- prandial changes ($F\ (1,128) = 5.71$, $p < 0.02$, $\eta_p^2 = 0.04$), with no gender differences ($F\ (1,128) = 0.22$, $p = 0.64$, $\eta_p^2 < 0.01$). Participants generally arrived with low or moderate levels of hunger (mean ± SD) was 40.97 ± 16.41, on a 0 - 100 scale. Levels of hunger rose incrementally from the first session to a maximum (67.96 ± 15.99) before the fruit meal ($F(1,97) = 44.86$, $p < .001$, adj $R^2 = 0.32$), followed by a steep decline after consumption of the fruit (21.77 ± 13.79); $t(65) = 12.00$, $p < .001$, $r = .83$).

4.3.2.1. EBA performance

The primary measure of variability in implicit processing in Experiment 2 was again the accuracy of target detection (% of correct trials) at each test session for RSVP streams under the five different distractor conditions: neutral, fruit-specific, fruit-general, sandwich, and cheesecake.

4.3.2.2. Accuracy

Analysis of response accuracy at each test interval revealed a distinct effect of distractor type (F (4,620) = 14.34, $p < 0.001$, $\eta_p^2 = 0.08$), and a significant effect for session (F (3,620) = 30.62, $p < 0.001$, $\eta_p^2 = 0.13$). A significant effect of gender was also observed (F (1,620) = 11.58, $p < 0.001$, $\eta_p^2 = 0.02$), although this effect was small and was not found to interact with distractor type (F (4,620) = 0.27, $p = 0.90$, $\eta_p^2 < 0.01$) or session (F (3,620) = 1.31, $p = 0.27$, $\eta_p^2 < 0.01$). The main effect for session was, as for Experiment 1, influenced by an intial practise effect between T1 and T2. Therefore, subsequent analysis of response correctness utilised T2 as the baseline. Analysis of EBA response accuracy from T2 to T4 indicated distinct differences between distractor types (F (4,465) = 13.20, $p < 0.001$, $\eta_p^2 = 0.10$), over time (F (2,465) = 3.80, $p = 0.02$, $\eta_p^2 = 0.02$). However, as in Experiment 1, these factors were not found to interact with time, and therefore consumption (F(8,465) = 0.38, $p = 0.93$, $\eta_p^2 = 0.01$).

Table 4.3.2. Pre-prandial (T3) for target detection accuracy by distractor type

		Mean ± SD		Statistics	
Distractor 1	Distractor 2	Distractor 1	Distractor 2	t-value	*p-value*
Neutral	Fruit-Specific	67.58 (17.95)	62.95 (15.83)	2.12	0.04
Neutral	Fruit-General	67.58 (17.95)	62.05 (17.36)	2.24	0.03
Neutral	Sandwich	67.58 (17.95)	55.30 (19.09)	6.14	<0.001
Neutral	Cheesecake	67.58 (17.95)	53.26 (18.53)	5.65	<0.001
Fruit-Specific	Fruit-General	62.95 (15.83)	62.05 (17.36)	0.46	0.65
Fruit-Specific	Sandwich	62.95 (15.83)	55.30 (19.09)	2.81	<0.01
Fruit-Specific	Cheesecake	62.95 (15.83)	53.26 (18.53)	4.48	<0.001
Fruit-General	Sandwich	62.05 (17.36)	55.30 (19.09)	2.36	0.02
Fru General	CC	62.05 (17.36)	53.26 (18.53)	3.75	<0.001
Sandwich	CC	55.30 (19.09)	53.26 (18.53)	0.70	0.49

Note. Fru = Fruit, CC=Cheesecake, Df = 32.

As Fig. 4.3.2 illustrates, the food distractor categories differed in their relative ability to capture attention. Both categories of fruit distractor produced relatively modest reductions in response accuracy, which were apparent only before the test meal (see Tables 4.3.2 and 4.3.3. for statistics). Nevertheless, before the test meal accuracy for fruit distractor streams was reliably reduced compared to neutral streams. By contrast, both sandwich and cheesecake distractors markedly reduced accuracy relative to both neutral and fruit distractors; effects that were apparent both before and after consumption of the test meal.

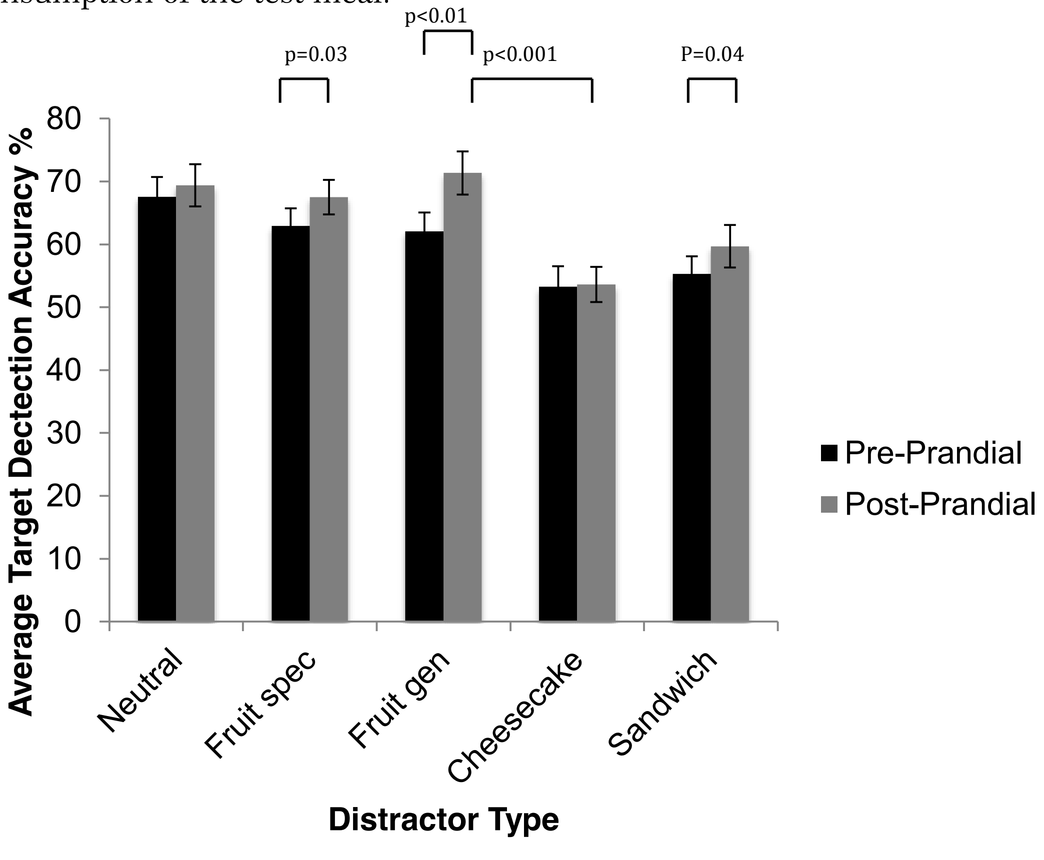


Figure 4.3.2. Average pre- and post-prandial EBA target detection

Comparison of response accuracy immediately before and after fruit consumption confirmed the influence of distractor types (F(4,320) = 8.84, $p < 0.001$, $\eta_p^2 = 0.10$), and of the meal (F(1,320) = 4.41, $p < 0.05$, $\eta_p^2 = 0.01$).

Although no interaction was evident (F(4,320) =0.61, $p = 0.65$, $\eta_p^2 < 0.01$), pairwise comparisons for each distractor type revealed significant post-meal increases in accuracy for both fruit-specific ($t(32) = 2.33$, $p = 0.03$, $r = 0.38$) and fruit-general images ($t(32) = 3.27$, $p < 0.01$ $r = 0.50$). Consequently, at T4, accuracy levels for both fruit distractor categories were no longer different from neutral. An improvement in accuracy was also evident for sandwich distractors ($t(32) = 2.12$, $p = 0.04$, $r = 0.12$). There was no change in attention to cheesecake distractors ($t(32)= 0.18$, $p = 0.86$, $r = 0.03$) or – as anticipated, neutral distractors ($t(32) = 0.97$, $p = 0.34$, $r = 0.17$).

Finally, meal-related changes in appetite (AVAS: T3-T4) were found to predict changes in attention (T3-T4) to fruit-general images, $b = -0.42$, $t(31) = 2.6$, $p = 0.01$, and predicted a significant proportion of variance performance of change in target detection in fruit-general streams, adj$R^2 = 0.15$, $F(1, 31) = 24.39$, $p < .001$. However changes in appetitive ratings on the AVAS were not found to relate with changes in attention to other streams.

Table 4.3.3. Post-prandial means (±SD) for target detection accuracy by distractor type

		Mean Scores		Statistics	
Distractor 1	Distractor 2	Distractor 1	Distractor 2	t-value	*p-value*
Neutral	Fruit-specific	69.39 (19.28)	67.50 (15.87)	0.79	0.43
Neutral	Fruit general	69.39 (19.28)	71.36 (19.67)	1.22	0.23
Neutral	Sandwich	69.39 (19.28)	59.70 (19.05)	4.63	<0.001
Neutral	Cheesecake	69.39 (19.28)	53.64 (16.05)	8.21	<0.001
Fruit-specific	Fruit-general	67.50 (15.87)	71.36 (19.67)	1.52	0.14
Fruit-specific	Sandwich	67.50 (15.87)	59.70 (19.05)	2.88	<0.01
Fruit-specific	Cheesecake	67.50 (15.87)	53.64 (16.05)	6.16	<0.001
Fruit-general	Sandwich	71.36 (19.67)	59.70 (19.05)	4.80	<0.001
Fruit-general	Cheesecake	71.36 (19.67)	53.64 (16.05)	8.30	<0.001
Sandwich	Cheesecake	59.70 (19.05)	53.64 (16.05)	2.77	<0.01

Note. CC=Cheesecake, Df = 32.

4.3.2.3. Reaction time

Analysis of reaction times across the experiment revealed significant effects of session (F(4,617) = 49.62, $p<0.001$, $\eta_p^2 = 0.19$), and gender (F(1,617) = 6.83, $p<0.01$, $\eta_p^2 = 0.01$) with males being, moderately quicker to respond (Males: 0.24 ± 0.06, Females: 0.25 ± 0.07). However, changes in reaction time were not influenced by distractor type (F4,617) = 0.001, p = 0.98, $\eta_p^2 < 0.001$), and there was no interaction between distractor type and session (F(12,617) = 0.002, p=1.00, $\eta_p^2 < 0.001$). As with previous experiments, reaction times reduced from T1 to T3 for all distractor stream types, before stabilising; again reflecting a practice effect.

4.3.2.4. Affective State

As summarised in Figure 4.3.3, analysis of PANAS scores revealed similar trends to those reported earlier. Initially high PPANAS scores gradually declined over the pre-meal phase (F (3,124) = 3.43, p = 0.02, $\eta_p^2 = 0.07$) to reach a minimum at T3. After fruit consumption there was a marked rise in PPANAS scores (t(32)= 4.08, $p<0.001$, r =0.58). A time-dependent variation in NPANAS scores was also evident (F (3,124) = 4.03, $p < 0.01$, $\eta_p^2 = 0.09$. Relatively low scores were maintained across the pre-prandial period, but a significant reduction in NPANAS was observed following fruit consumption (t(32)= 4.71, $p<0.001$, r =0.64).

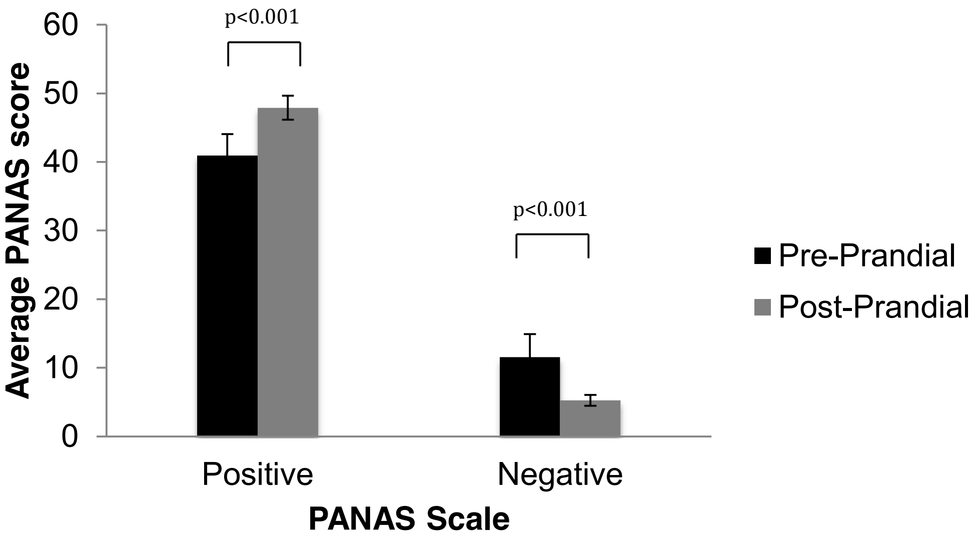


Figure 4.3.3. Average pre- and post-prandial average PANAS ratings

Interestingly, changes in PPANAS between T3 and T4 moderately predicted by changes in appetite, b = -0.66, $t(31) = 2.58$, $p < 0.001$. Change in appetite also predicted a significant proportion of variance in positive affect, adj$R^2 = .42$, $F(1, 31) = 24.39$, $p < 0.001$.

4.3.2.5. Valence scores

A comparison of valence ratings of filler and distractor images used in the study revealed a significant effect of image type (F (5,384) = 12.37, p < 0.001, $\eta_p^2 = 0.14$), with cheesecake images being rated more highly than all other foods, both before and after the test meal (T3 = 72.44 ± 14.12; T4 = 71.23 ± 13.17; see summary Fig 4.3.4). A trend for valence rating change was also found between pre- and post-prandial sessions (F (1,384) = 3.05, p = 0.08, $\eta_p^2 = 0.01$), attributable specifically to a post-meal decline in ratings. of both fruit-specific (t(32)= 10.05, p<0.001, r =0.87) and fruit-general images (t(32)= 11.10, p<0.001, r =0.89). No change was detected for the valence of sandwich (t(32)= 1.78, p=0.08, r =0.30) or cheesecake images (t(32)= 1.64, p=0.11, r =0.28). Ratings of non-food images were also unaffected.

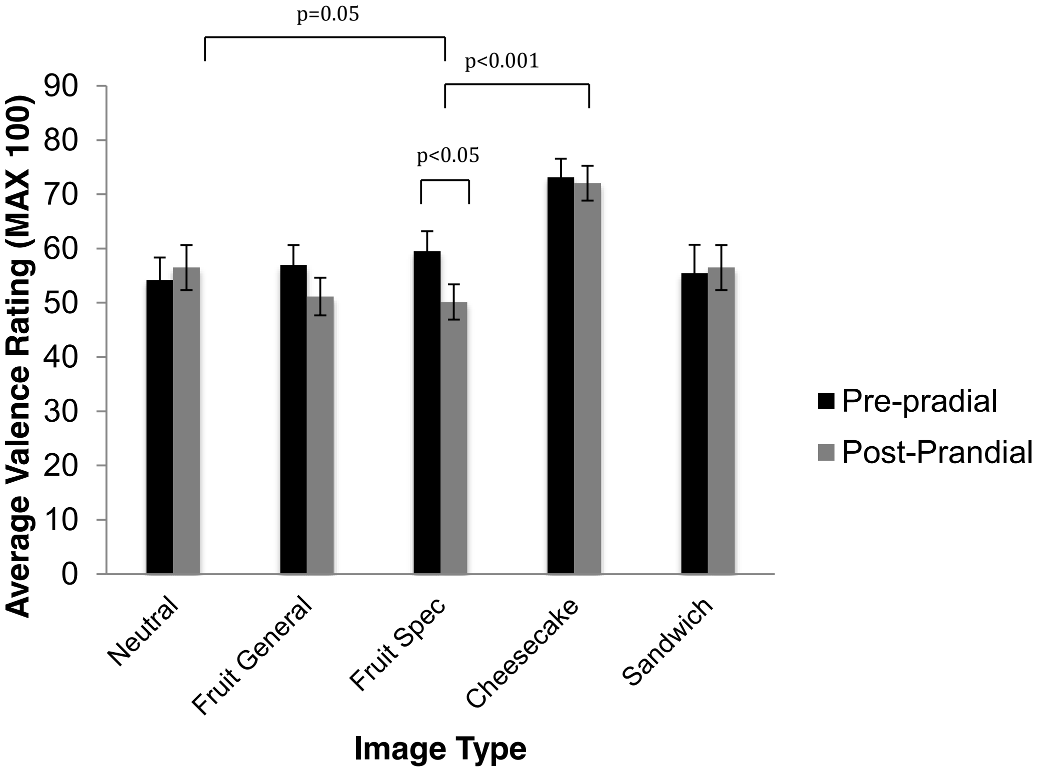


Figure 4.3.4. Average pleasantness ratings pre- and post prandial

Changes in valence ratings did not correlate with changes in attention.

4.3.3. Discussion

Unlike Experiment 1, where attention to images of the palatable cheesecake was unaffected by its consumption, this experiment found that attention to the *category* of food consumed (i.e., both fruit-specific and fruit-general) was changed following satiation. The attentional consequences of consuming fruit to satiety where therefore very similar to those following sandwich consumption described earlier. Satiety following fruit consumption was also found to be accompanied by reductions in the attentional capture by sandwich images. Arguably, this change reflects a general decline in motivation to eat and responsiveness to a broad range of food stimuli, since sandwiches were not consumed nor do they share the sensory characteristics of fruit. By contrast, the replication of the magnitude and persistence of the ability of cheesecake distractors to capture attention, even after participants reported low appetite levels, suggests that cheesecake possesses intrinsic properties that differ from the other food types. Although fruit and cheesecake share some sensory features (principally sweetness), in this experiment pleasantness ratings of cheesecake exceeded those for all other food types – and to a similar degree both before and after the meal. It is likely that previous experience of the intense hedonic qualities of eating cheesecake gives the food a high incentive salience that is sufficient to attract attention and promote its consumption even when we are already sated on other foods. Such an explanation clearly matches common experience and culinary practice, whereby further consumption can be promoted by proffering attractive, delicious foods – commonly described as the dessert effect,

A secondary finding was the replication of the close association between affect and appetite. Thus, PPANAS scores were lowest immediately before the test mail, when motivation to eat was highest, while satiety was associated with an increase in positive affect. Conversely, high, pre-meal appetite ratings and post meal satiety reflected respective increases and reductions in negative affect. Since satisfying one's appetite improves affective state – reflecting the rewarding consequences of food and eating, we might predict that manipulating affect would alter attention to food stimuli independently of endogenously generated levels of eating motivation? Indeed, there is experimental evidence to indicate that negative affect can increase appetite (e.g. Macht, 2008). Such an effect is generally interpreted in terms of negative reinforcement with, for example, comfort foods alleviating a negative mood. The current data suggest that attentional mechanisms cooperate with emotional processes to orient the individual toward beneficial features in the environment.

4.4. General Discussion

The aim of these experiments was to build on previous findings by investigating whether temporal changes in motivation to eat induced by the prospect and consumption of desirable, sweet foods would interact with attentional processing of food stimuli and replicate the sensory-specific adjustments that we obtained when participants ate sandwiches to satiety. In addition, both experiments explored the relationships between implicit processing and explicit evaluations (pleasantness) of food-related stimuli, and changes in appetite and affective state. Naturalistic changes in appetitive state impacted on attentional processing of food in Experiment 2, following the consumption of fruit to satiety. The same effect was not observed in the Experiment 1. In that case, distractors representing cheesecake retained their ability to capture attention at the same level throughout, irrespective of appetite level, or having sated on cheesecake.

These disparate findings occurred despite explicit ratings of the pleasantness of the test food consumed in each experiment declining following consumption, and similar changes in appetite being recorded after each test meal. Comparisons of the results from each experiment have a number of important theoretical implications in the context of the previous literature, which in turn have implications for the refinement of incentive salience theory and SSS.

The primary finding of Experiment 1 was that attentional processing of cheesecake images, which were explicitly rated as highly pleasant, captured attention regardless of fluctuations in appetitive state. This novel finding appears to be the first occurrence in which attention to a specific food category appears to be consistent over time, and independent of appetitive state. Previous studies have typically found that the hedonic value of food is modulated by appetite – increasing when hungry and declining after the food has been eaten to satiety (Cabanac, 1971; Winkleman and Berridge, 2003), Additionally, studies of implicit processing usually find that attention to food-related stimuli is greater in the fasted state than when sated (di Pellegrino et al., 2011; Mogg et al., 1998; Piech et al., 2010). However, only Di Pellegrino et al (2011) have previously investigated changes in attentional responses to different food types and explicit ratings of their pleasantness, relative to whether or not they were consumed. They found that attention to a food eaten to satiety, and its rated pleasantness, are reduced in comparison to other, non-consumed foods. These effects are follow the expectations of incentive salience theory and SSS, namely that changes in 'wanting' or appetitive state will decrease the hedonic value of food and therefore the foods salience. With particular regard to SSS, these reductions in hedonic-value would be specific to the food consumed. Only Experiment 2 reflects this, with the consumption of fruit reducing attention to fruit as a category, not just to the specific food eaten as reported by Di Pellogrino et al (2011).

Studies investigating the influence of consuming sweet foods on food pleasantness, have reported that desserts, with high baseline valence ratings, yielded smaller alliesthesic effects (i.e., a postprandial decline in pleasantness) than other food categories (Stoeckel et al., 2007). Investigations into pleasantness using sucrose solutions of different concentrations have shown that alliesthesia may vary inversely with hedonic ratings among participants who disliked high concentrations of sucrose. While an investigation of sensory-specific satiety resulting from consumption of meals of varied composition, also displayed an inverse relationship between allesthesia and hedonic rating, relative to sweet food (J. Johnson & Vickers, 1992a). Despite this participants often report preferences for sweet foods with both high carbohydrate and fat contents (Wansink, Cheney, & chan, 2003). Stoeckel et al state "that observed difference in magnitude of alliesthesia as a function of valence may reflect the ability of the high hedonic value of dessert foods to partially override the inhibitory effect of satiety". The effects seen in the two experiments presented here may indeed result from extreme values. Previous research by Nummenmaa et al (2011) has replicated similar results finding participants detect appetising foods more easily than bland or non-foods, in a visual search task. The present experiments build on this, showing that implicit processing of food-related stimuli may depend on their associated hedonic values more than the individual's appetitive state.

Due to the fundamental mechanisms underlying attentional processing it is hardly surprising that changes in food liking, do not always relate to changes in the attentional processing of food. A few previous studies have found that changes in pleasantness relate to changes in attention (di Pellegrino et al., 2011; Hogarth, Dickinson, Hutton, Elbers, & Duka, 2006; Waters et al., 2009). The explicit ratings of pleasantness in both experiment 1 and 2 displayed typical SSS changes in pleasantness ratings relative to appetite (i.e., ratings of the consumed food declined with satiation following consumption of the specific food).However attentional processing differed between the two experiments, with experiment 1 demonstrating that attention to foods like cheesecake may be resistant to changes in appetite, while experiment 2 found the opposite. A key factor influencing these dichotomous findings between the explicit and implicit measures may be knowledge of consumption (explicit) compared to the underlying implicit value of food. Basically the differences in attentional performance may relate to the underlying hedonic value of food influencing salience attribution, with more powerful stimuli being resistant to changes in appetite. While explicit measures may be influence by the knowledge of consumption, and feeling of fullness from the volume consumed. Which may be a consequence of the powerful influence highly-rated hedonic stimuli have on the salience attribution.

Recently, several researchers have suggested that a defect in SSS mechanisms could increase food intake (Brondel et al., 2006). Although a body of research has found no difference between food-selection, taste-preferences and hedonic sensations (Cox et al, 1999). While Blundell and Hill (1998) have found that lean individuals displayed negative alliesthesia in response to the consumption of sweet solutions, while obese individuals were unaffected. However, it is clear that humans have evolved to satisfy their immediate needs (van den Bos & de Ridder, 2006), while preserving high hedonic values for certain foods may enhance opportunistic feeding strategies. As Kirkham (Kirkham, 2009) states "If our opportunistic susceptibility to overconsumption does constitute a component of a regulatory regime, then it may most easily be regarded as one that increases the likelihood that future energetic demands will be met – to support the truly homeostatic, moment-to-moment maintenance of cellular fuel availability. Overeating then is not counter-regulatory, but represents the most effective behavioural mechanism for ensuring that energy input can match future requirements". In essence humans and animals alike are predisposed to opportunistically act upon objects with a high hedonic value, regardless of state. While other items may be less appealing. However it is likely that explicit processing can over come these implicit mechanisms influencing salience attribution and attention, seen in the form of sensory specific satiety. We suggest as others have done that explicit and implicit 'wanting' systems are distinct but interacting systems (Berridge et al., 2009; Finlayson et al., 2008). And that it is the explicit knowledge of consumption that restricts food intake, and pleasantness, as implicit processes would allow an individual to continue eating without this knowledge.

A final but crucial finding from these experiments was the consistent relationship between changes in appetite and changes in positive affective state. Both studies found that satiation increased positive affect, while positive affect decreased with increases in appetitive state. As Panksepp (Panksepp, 2011a; 2011b) has highlighted, affective processes play a vital role in motivational processes and responsiveness to environments.

Panksepp (Panksepp, 2011a; 2011b) suggests that affect acts as an inbuilt valuing system that is refined, like stock exchanges, through our interactions and experience with the world. Vitally, this affective system acts at an implicit level influencing the ‘liking’ process of motivation (Berridge & Winkielman, 2003), therefore influencing hedonic values and subsequent salience of motivational ‘objects’ such as food. A number of previous studies have previously shown that negative priming or negative moods may increase attention to food {Werthmann:2014bp, MacLeod:2002vk, Hepworth:2010kv}, possibly as a means of using rewarding stimuli to decrease negativity. While other studies have shown that positive moods increase attention to rewarding stimuli (Becker & Leinenger, 2011; Goetz, Robinson, & Meier, 2008; Koole & Rothermund, 2011; Tamir & Robinson, 2007). The present findings provide further support for the relationship between motivational drives and the reinforcing nature of satisfying needs experienced at an explicit level. However if food consumption increases explicit ratings of positive affect might the opposite be true? Could inducing positive affect increase attention to motivational stimuli, such as food or/and the explicit ratings of food. A large sector of the advertising industry is certainly based on this premise.

Limitations

Visual stimuli are theorised to capture attention as a result of their motivational significance (Berridge & Kringelbach, 2015; Berridge & Robinson, 1998; Ferrari, Codispoti, Cardinale, & Bradley, 2008). However, another explanation for their potency may lie in their novelty. Attentional processing of motivationally salient objects has not been distinguished from novelty seeking (Tomer, 2008). Novelty is known to be a potent signal that attracts attention, causes a rapid orienting reaction and promotes learning (Knight, 1996; Lisman & Grace, 2005; Mesulam, 1998). Furthermore, Tulving’s novelty encoding hypothesis (Tulving, Markowitsch, Craik, Habib, & Houle, 1996) suggests that information encoding varies with the novelty of information received. From an evolutionary perspective, the preferential processing of novel stimuli acts as an important mechanism in motivating individuals to explore new environments for new sources of reward (Dayan & Sejnowski, 1996; Kakade & Dayan, 2002). According to Panksepp (Panksepp, 2011a) this mechanism is essential to the survival of any foraging species. Distinguishing between stimuli that have relevance to specific motivations arising out of biological need, or that capture attention merely because they are novel may be vital for disentangling implicit and explicit motivational processes.

Table 4.3.4. Pre-prandial valence ratings of image types

		Mean Scores (±SD)		Statistics	
Distractor 1	Distractor 2	Distractor 1	Distractor 2	t-value	*p-value*
Neutral	Fruit Specific	56.46 (12.33)	60.47 (16.00)	1.08	0.29
Neutral	Fruit General	56.46 (12.33)	58.82 (16.79)	0.63	0.53
Neutral	Sandwich	56.46 (12.33)	59.21 (19.25)	0.98	0.33
Neutral	Cheesecake	56.46 (12.33)	72.44 (14.12)	4.17	<0.001
Fruit Specific	Fruit General	60.47 (16.00)	58.82 (16.79)	2.44	0.02
Fruit Specific	Sandwich	60.47 (16.00)	59.21 (19.25)	0.27	0.79
Fruit Specific	Cheesecake	60.47 (16.00)	72.44 (14.12)	7.31	<0.001
Fruit General	Sandwich	58.82 (16.79)	59.21 (19.25)	0.09	0.93
Fruit General	Cheesecake	58.82 (16.79)	72.44 (14.12)	4.75	<0.001
Sandwich	Cheesecake	59.21 (19.25)	72.44 (14.12)	2.44	0.02

N.B. Df = 32.

Table 4.3.5: Post-prandial valence ratings of image types

		Mean Scores (±SD)		Statistics	
Distractor 1	Distractor 2	Distractor 1	Distractor 2	t-value	*p-value*
Neutral	Fruit Specific	59.14 (12.50)	51.74 (15.10)	2.02	0.05
Neutral	Fruit General	59.14 (12.50)	53.88 (16.19)	1.42	0.16
Neutral	Sandwich	59.14 (12.50)	57.33 (17.18)	0.61	0.54
Neutral	Cheesecake	59.14 (12.50)	71.23 (13.23)	3.22	<0.01
Fruit Specific	Fruit General	51.74 (15.10)	53.88 (16.19)	2.26	0.03
Fruit Specific	Sandwich	51.74 (15.10)	57.33 (17.18)	1.31	0.2
Fruit Specific	Cheesecake	51.74 (15.10)	71.23 (13.23)	7.31	<0.001
Fruit General	Sandwich	53.88 (16.19)	57.33 (17.18)	0.83	0.41
Fruit General	Cheesecake	53.88 (16.19)	71.23 (13.23)	6.06	<0.001
Sandwich	Cheesecake	57.33 (17.18)	71.23 (13.23)	2.38	0.02

N.B. Df =32

Chapter 5:

Affective salience: Investigating the influence of affective priming on motivational processing

5.1. Introduction

The acquisition of essential nutrients and the maintenance of positive energy balance constituted fundamental influences in the evolution of the neuropsychological systems that energize and guide an organism's behaviour. In our ancestral environment, the necessity to obtain food for daily sustenance, and for the accumulation of energy reserves to protect against future privation, led to the evolution of multifaceted mechanisms that promote food seeking, prioritize the detection of food, and reward its consumption (Kirkham, 2009). The drive to eat and the direction of food-seeking and feeding behaviour can, consequently, be considered to involve complex interactions between motivational, attentional and emotional systems (Gable & Harmon-Jones, 2010a; Goetz et al., 2008; Panksepp, 2011a).

The attribution of salience, otherwise known as incentive salience, is argued to account for the process by which organisms seek out rewarding events or objects (Berridge et al., 2009; Berridge & Robinson, 1998; Robinson & Berridge, 1993; 2008b). Incentive salience suggests that the rewarding nature of interactions between organisms and rewarding objects or environments lead relative stimuli, such as food, or conditions to become attractive and attention grabbing, particularly when an organism is in a state of need (Berridge & Kringelbach, 2015). Crucially the potency or importance of rewarding stimuli may be so strong as to induce motivation to seek out rewarding stimuli: e.g., hunger motivates humans to seek out food.

Considering attentional processes, the visual system exhibits a demonstrable preparedness for the detection of food-related stimuli, facilitating the rapid detection of potential food sources — even in the absence of overt need. Thus, Nummenmaa et al. (Nummenmaa et al., 2011) showed that visual attention is preferentially biased toward nutritive targets, particularly those that exhibit specific categorical shape-colour features that distinguish foods from non-foods. Such a bias would of course be particularly advantageous in states of *extremis*, and several studies have indicated that hunger may enhance attention to food cues (see di Pellegrino et al., 2011; Piech et al., 2010). For example, hungry individuals can display an enhanced attentional bias to food-related words or food images in visual probe and eye-tracking studies (Castellanos et al., 2009; Loeber et al., 2013; Mogg et al., 1998; I. Nijs, 2010; Placanica et al., 2002) and Stroop tasks (Channon & Hayward, 1990; Lavy et al., 1994).

Hedonic value and motivational state have substantial influence over responsiveness towards food. These factors focus on internalized processing of motivational state relative to objects and the experience of these objects. However environments provide us with immense quantities of information, which may contextualise our evaluations of objects within them. Affective systems are thought to play a significant role in assessing environmental complexity to influence decisions at both an explicit (Isen & Reeve, 2006) and implicit level (De Houwer et al., 2009; Dreisbach & Goschke, 2004). While recent neuroimaging evidence suggests that affective information may regulate attentional processing (Carretié et al., 2001; Vuilleumier, 2005). The neurocognitive architecture of motivational and affective systems are closely related and it has been suggested that affective information or state acts as a gating system to which interacts with motivation to influence attentional systems (Panksepp, 2011b). Support for this comes from research demonstrating that priming affective states may increase attention to rewarding stimuli (Becker & Leinenger, 2011; Goetz et al., 2008; Koole & Rothermund, 2011; Tamir & Robinson, 2007).

There are also various indications that affective state can alter the motivation to eat (e.g. Macht, 2008). In particular, there is a substantial literature linking negative affect to increased appetite, arguably as a result of the increased reward value of comfort foods through the operation of negative reinforcement mechanisms (Bekker et al., 2004; Bongers, van den Akker, Havermans, & Jansen, 2015; Willner et al., 1998). To date, the influence of positive affect on eating motivation has been less extensively studied, and unfortunately there is no general consensus within the literature. Positive emotional states have been variously reported to increase (Bongers, Jansen, Houben, & Roefs, 2013; Evers et al., 2009; 2013; Macht et al., 2002), decrease (Turner et al., 2010), or to have no effect on appetite or eating (Lowe & Fisher, 1983; Yeomans & Coughlan, 2009).

There have been numerous demonstrations that affective state can also modulate visual-spatial attentional processes, building a longstanding, consensus that negative states act to narrow the scope of attention while positive emotions broaden attentional focus and facilitate responding to peripheral cues (Fredrickson & Branigan, 2005; Gasper & Clore, 2002; Rowe et al., 2007). However, and of particular relevance in the current context, the influence of positive affect on attentional scope may actually depend upon motivational intensity and orientation (Gable & Harmon-Jones, 2012). Hence, Gable and Harmon-Jones (Gable & Harmon-Jones, 2010b) have argued that approach-motivated, positive affective states associated with biological imperatives, such as the desire and search for food, should be associated with attentional narrowing to exclude extraneous stimuli and so facilitate the detection and acquisition of goal objects. Indeed, such a tendency for narrowing attentional scope has been observed in studies that have assessed attentional breadth following the presentation of images of desirable foods, specifically designed to induce high approach-motivated positive affect (Gable & Harmon-Jones, 2008; 2010b).

Examination of the temporal aspects of attention also reveals the impact of emotional or motivational salience of visual stimuli; exemplified by studies using techniques in which the presentation of a task-irrelevant, but salient, distractor image can induce an attentional blink that reduces an individual's ability to subsequently detect a specific target within a rapid serial visual presentation (RSVP; McHugo, 2013; Mohanty & Sussman, 2013; Most et al., 2005). Using RSVP tasks with pictures of energy-dense, highly palatable foods as targets or distractors, Neimeijer et al. (Neimeijer, de Jong, & Roefs, 2013) found that food cues can elicit an attentional blink, such that correct identification of a target image was significantly less likely when it was preceded by a picture of food. These data, in line with those of the aforementioned study by Nummenmaa et al. (2011), indicate that food stimuli gain preferential access to cognitive processing. Moreover, there is good evidence that this preferential allocation of resources can be modified when the salience of food stimuli are altered by manipulation of the level of motivation to eat. Notably, an earlier study by Piech and colleagues (2009), using an emotional blink of attention (EBA) paradigm, reported that food distractor images more effectively induced an attentional blink in individuals when they were fasted than when they were sated. This effect was obtained despite the fact that participants were given monetary incentives to perform well on the target identification task; indicating again that hunger can involuntarily bias perception to attend to food cues that fulfil an urgent biological need.

On the basis of the above — an innate attentional bias for food that is evident in the absence of need but that is modified by hunger or satiety, and the noted separate influences of emotional factors on attention and appetite — we might expect that manipulation of affective state would also have some impact upon the specific ability of food to capture attention — reflecting the accepted reciprocal links between attentional, motivational and emotional systems (Compton, 2003; Winkielman et al., 2007; Yiend, 2010; Nummenmaa et al., 2011; Raymond et al., 2003).

The very few studies that have so far examined how affective states alter attention to food stimuli have focused solely on the impact of negative states, and have produced contradictory findings. For example, Hepworth et al., (2010) reported that induction of negative mood increased selective attention to pictorial food cues in a visual-probe task; arguing that negative affect increases the reward value of, and hence the attentional bias to food. However, using an eye-tracking paradigm, Werthmann et al. (2014) were unable to replicate that finding.

A specific effect of positive emotion on attention to food thus remains unexplored and, given the contradictory findings regarding positive affect and appetite noted above, it is difficult to predict the direction of any relationship. However, it has been proposed that positive affect might have a generalised action to bias attention towards rewarding stimuli and facilitate the acquisition of desirable goals (Becker & Leinenger, 2011; Goetz et al., 2008; Tamir & Robinson, 2007). For example, Tamir and Robinson (2007) found that induction of a positive mood selectively promoted the direction of attention to reward words in dot probe tasks. Those authors argued that their findings supported a reward-based model of positive affect, such as that of Berridge and Robinson (Berridge & Robinson, 1998; T. E. Robinson & Berridge, 2008a), and they specifically proposed that further studies should focus on investigating the appetitive cognitive consequences of positive mood. However very little has been done to investigate the influence of affect on motivational processing.

To assess these questions, we adopted a modified EBA paradigm that combines the method of Piech et al. (2009) together with a form of affective priming. As noted above, by using food images as distractors within a RSVP, Piech and colleagues successfully demonstrated the influence of motivational state (hunger versus satiety) on the ability of food distractor images to induce an emotional blink: with food imagery more effectively capturing attention after fasting; arguably reflecting an increase in the incentive salience of food with hunger. As has been widely demonstrated, brief exposure to emotional facial expressions can elicit basic affective reactions that can result in behavioural change (e.g., Ekman, 1984; Murphy and Zajonc, 1993; Wong and Root, 2003). Notably, Winkielman et al. (2005) examined the impact of subliminal presentations of happy faces on the subsequent evaluation and consumption of a palatable beverage. They found that, in thirsty participants, the desire to drink and the volume consumed increased significantly after positive affective priming. Ratings of willingness to pay, and wanting, for more of the beverage were also increased - but not assessments of palatability, which is in line with a direct effect of priming to change the underlying affective state and increase the incentive value of the drink.

In the present studies, we sought to further examine the links between affective and motivational systems, and their influence on attentional processes. Working within the theoretical framework that adaptive behaviour, such as food seeking, involves co-operatively with affect systems (Frijda, 1999; Rolls, 2000; Panksepp, 2011; Winkielman et al., 2005), we hypothesised that inducing positive affective responses through priming could increase the salience of food stimuli that already possess intrinsic incentive value, and consequently increase their ability to capture attention. Accordingly, affective priming was invoked through the presentation of photographs of emotional faces as filler images within the RSVP stream of the EBA task, and their effect on the magnitude of attentional blink produced by food distractor images was assessed.

Specifically the experiment presented here builds on a previous, unpublished study in which we investigated the influence of positive affective priming on attentional processing of food or a neutral stimulus. In order to do this we adapted the EBA task utilised in Piech et al's (2009) EBA task, adding positive primes to half of the RSVPs (see figure 5.1.1).

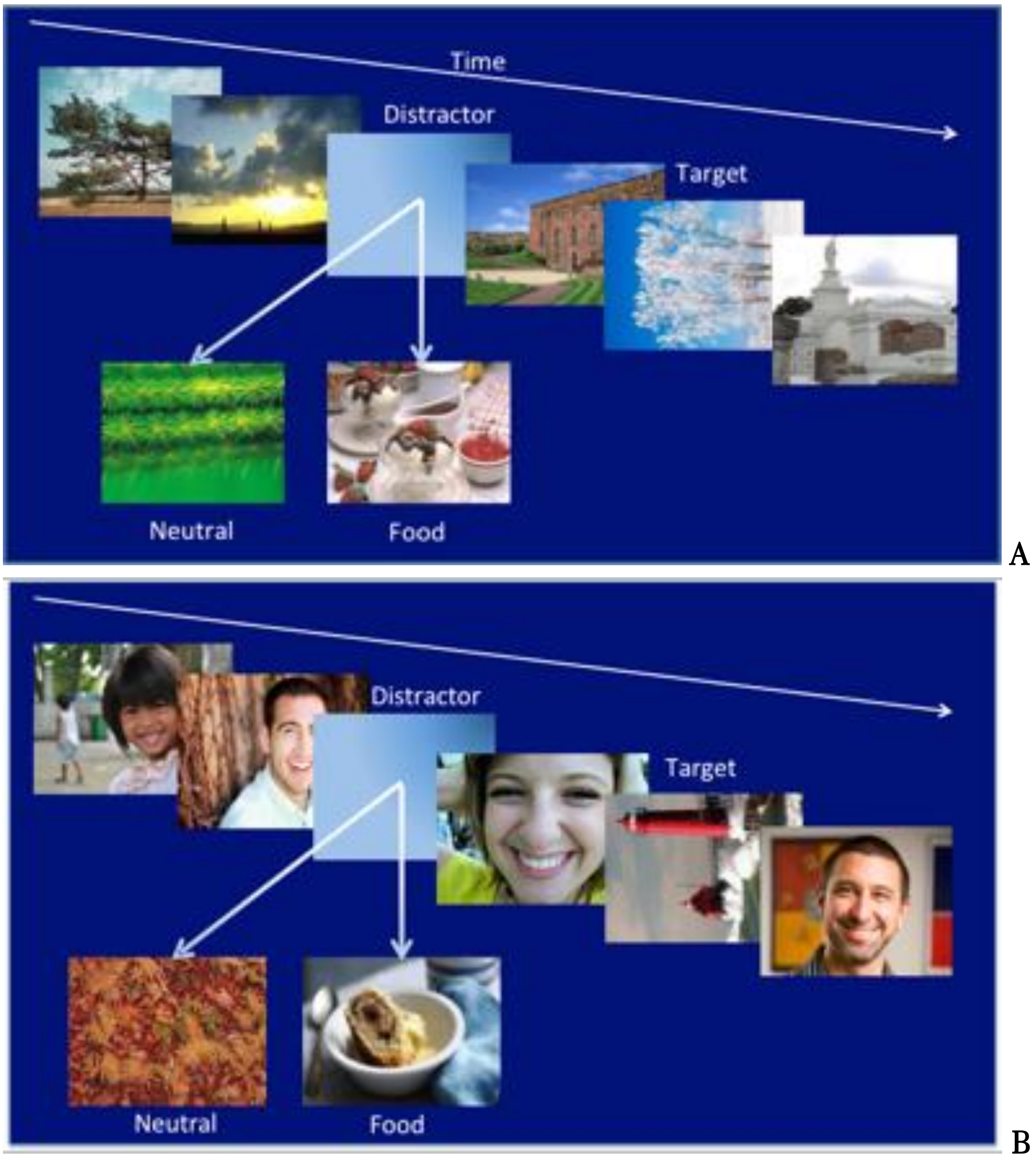


Figure 5.1.1. Representations of EBA trials for the neutral (A) and positive affective priming streams (B). In each trial, 17 images were each presented for 100 ms, with a target (rotated landscape) appearing either 2 or 4 presentations after a neutral or food distractor.

This study found that positive affective priming had a powerful influence on the ability of participants to detect a target if it was preceded by an image of food (F(1,116) = 45.33, p <0.001, partial $\eta^2 = 0.28$) (see figure 5.1.2). Positive emotional faces markedly reduced target accuracy by promoting attention capture by food distractors.

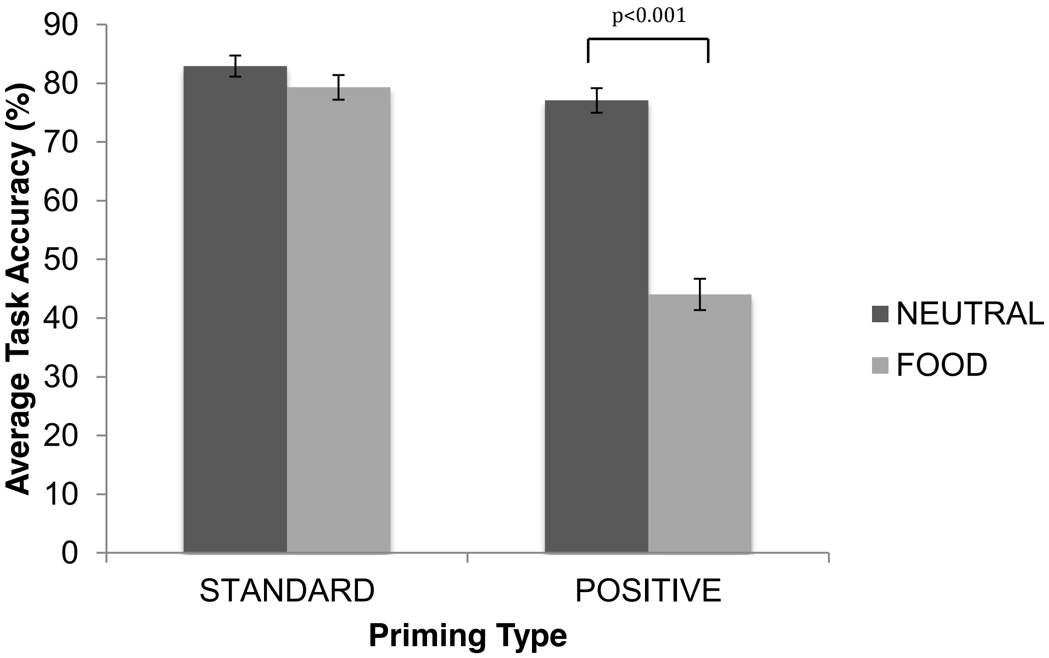


Figure 5.1.2. Influence of positive priming on attentional processing of food

In the following experiment, we sought to replicate this finding and also explore the consequences of negative priming using the same technique.

5.2. Method

5.2.1. Participants

One hundred and one adults were recruited from the same population as in Experiment 1 (27 males, mean age 21.7 ± 2.6 years; 78 females, mean age 19.79 ± 1.89 years).

5.2.2. *Visual stimuli*

Using the same format as previously described, 1031 photographic images (IAPS; Lang et al., 2001) were used as fillers, distractors or targets. The fillers were categorised as standard, negative or positive. Standard, neutral fillers were drawn from 256 landscapes or urban scenes. Positive emotional fillers were sampled from 137 images of smiling individuals. Negative emotional fillers used a bank of 127 images of people who appeared visibly upset or sad. Distractors belonged to either food, romantic or neutral categories. Food images were selected from 192 pictures displaying a variety of savoury meals or desserts. Romantic images were 40 photographs of heterosexual couples in romantic contexts. Neutral distractors were selected from 48 images of commonplace objects. Target images were landscapes rotated 90° to the right (n=136) or left (n=135).

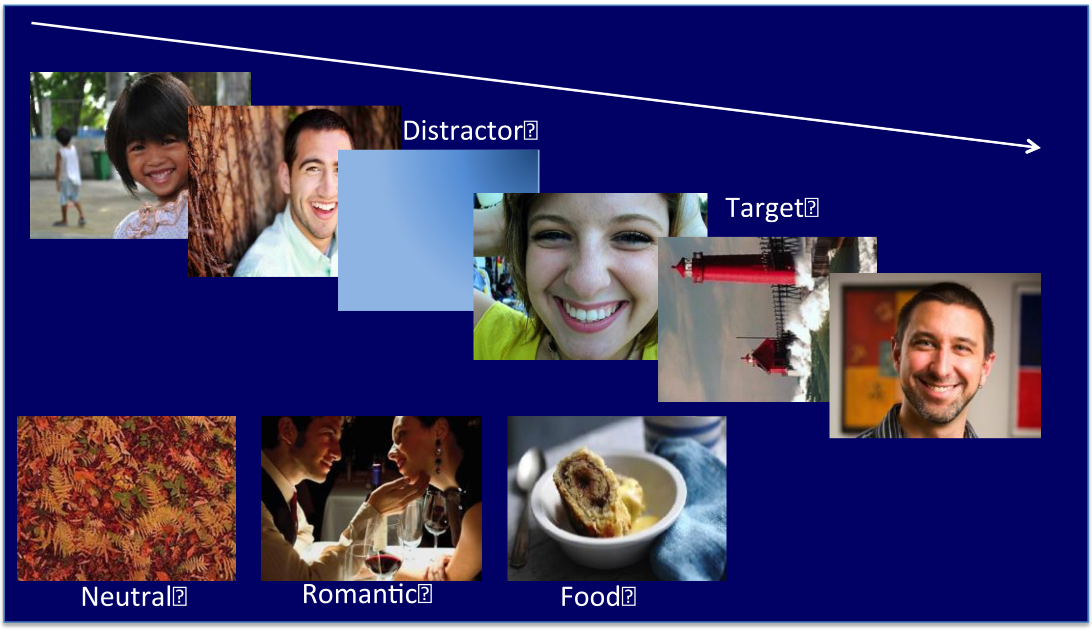
5.2.3. *Procedure*

The experiment used the same methodology as described for Experiment 1, with modifications necessary to incorporate the additional filler-distractor stimulus combinations, as noted below. In addition, participants were assigned to one of three priming groups: landscape/neutral, positive, and negative. Participants would be exposed to streams containing only one of the different filler image types; either landscape (neutral), negative emotional faces or positive emotional faces.

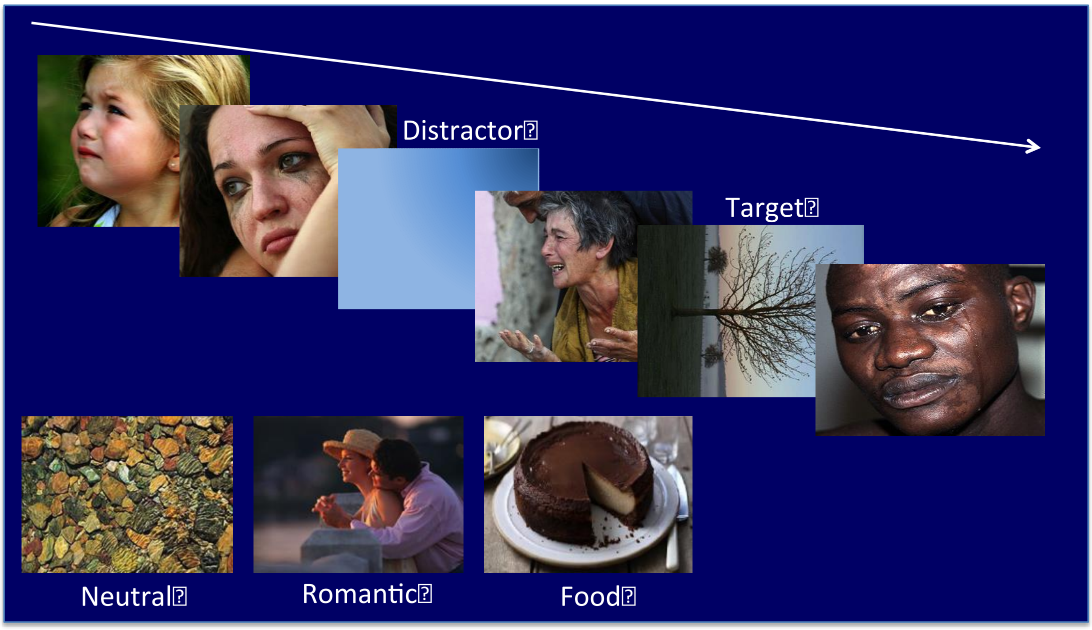
Participants were again tested at a time of day when motivation to eat was not expected to be high (after lunch, between 13:00 and 17:00). Appetite (AVAS) and affective state (PANAS) ratings were completed both before and after the EBA task. During the EBA, participants were exposed to a total of 120 streams divided between 4 blocks of 30 streams, with each block followed by a rest period. Streams of each filler-distractor combination (depending on the group, either standard, negative or positive emotional fillers, paired with neutral, romantic and food distractors) appeared randomly, but were evenly distributed across blocks (Figure 5.2.1).

Finally, participants completed a computerised valence-rating task, in which they rated 10 randomly selected images from each of the stimulus categories for pleasantness. The total duration of testing was approximately 9 minutes.

A



B



C

Figure 5.2.1. Representations of EBA trials for the neutral (A), positive affective priming (B), and negative priming (C) streams. In each trial, 17 images were each presented for 100 ms, with a target (rotated landscape) appearing either 2 or 4 presentations after a neutral or food distractor.

5.2.4. *Data Analysis*

Correctness of response and reaction time data for individual participant task performance on each stream type were determined. The data were checked for outliers with responses falling outside $k = 2.2$, as recommended by Hoaglin and Iglewic (1987). Differences in responses to stream types were analysed using 3 x 3 ANOVA, with priming groups as the between-subjects factor. The spread of data was analyzed further using correlational and regression analyses. *Post-hoc* analysis was conducted using the Tukey HSD procedure and independent t-tests. All statistics were conducted with R-studio.

5.3. Results

5.3.1. Appetite

Appetite was found to be stable over time with a strong relationship between AVAS ratings before and after eating (r (95) 0.75, p<0.001), with ratings generally increasing modestly from T1 to T2 (t(96) = -4.3, p <0.001, r = 0.4). An analysis of appetite by time and priming group found no difference between appetite scores for priming group (F (2,188) = 2.53, p = 0.08, partial $\eta^2 = 0.03$) or time (pre- compared with post EBA testing) (F (2,188) = 0.2, p = 0.82, partial $\eta^2 = 0.002$). The respective mean (± SE) AVAS ratings for each priming group are summarized in Fig. 5.3.1.

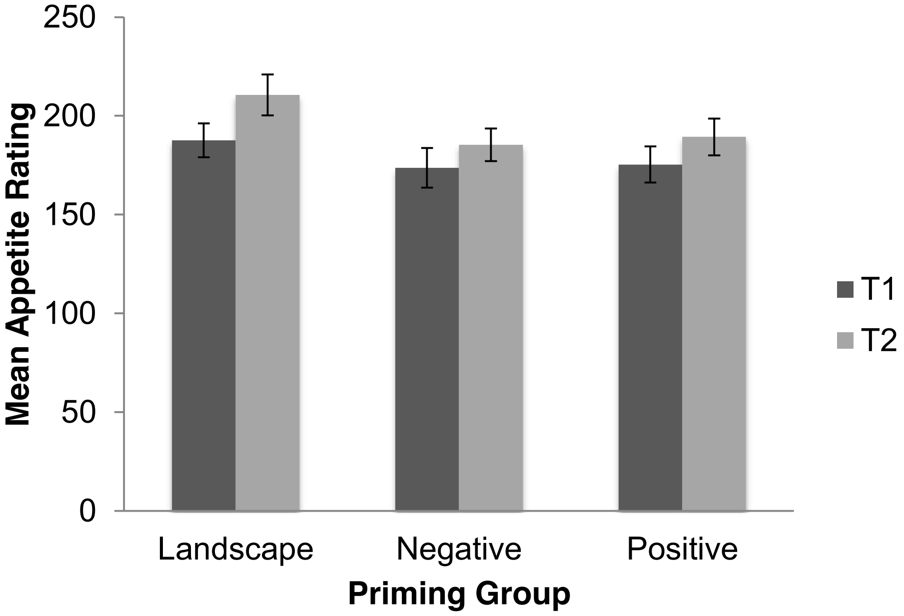


Figure 5.3.1. Comparison of appetite scores before (T1) and after (T2) EBA testing.

5.3.2. Affective state

Before testing, PANAS scores were similar for each priming condition (Fig. 5.3.2), with no statistical differences between groups for either NPANAS (F(2,94) = 0.42, p = 0.67, partial $\eta^2 = 0.01$) or PPANAS (F(2,94) = 0.6, p

= 0.55, partial $\eta^2 = 0.01$).

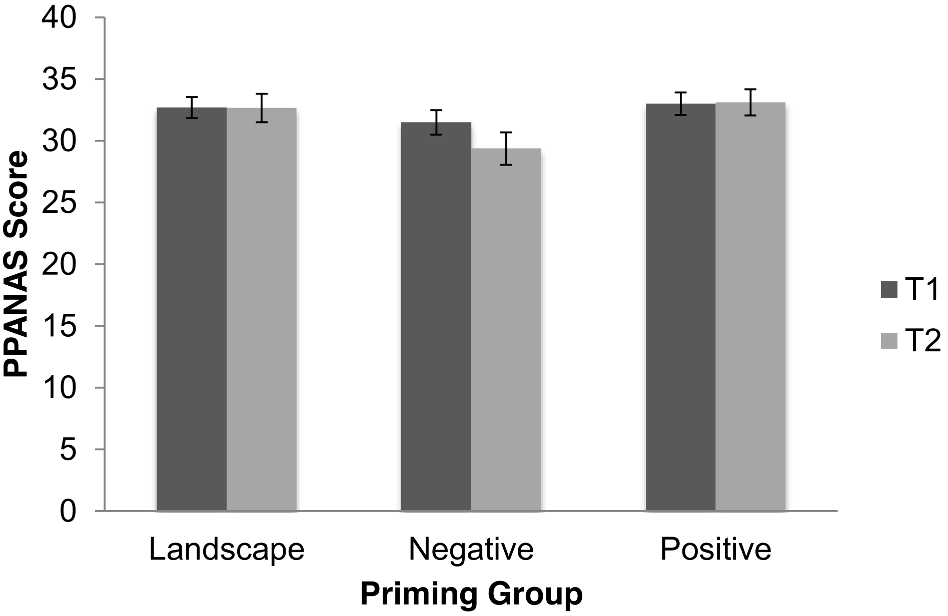


Figure 5.3.2. Comparison of positive scale PANAS score pre- and post EBA testing.

Comparison of PPANAS scores at T1 and T2 revealed a small of effect priming group (F(2,188) = 3.26, $p = 0.04$, partial $\eta^2 = 0.03$), although this did not interact with time (F(2,188) = 0.64, $p = 0.53$, partial $\eta^2 = 0.01$). By contrast, for NPANAS there was a reliable effect of time (F(1,188) = 9.44, p = <0.01, partial $\eta^2 = 0.05$), but no significant interaction with priming group (F(2,188) = 1.19, $p = 0.31$, partial $\eta^2 = 0.01$). These effects reflect significant reductions in NPANAS scores from T1 to T2 for participants in the positive priming condition (t(96) = 6.07, p <0.001, $r = 0.53$). Which was not repeated under landscape/neutral or negative priming conditions (see Fig. 5.3.3).

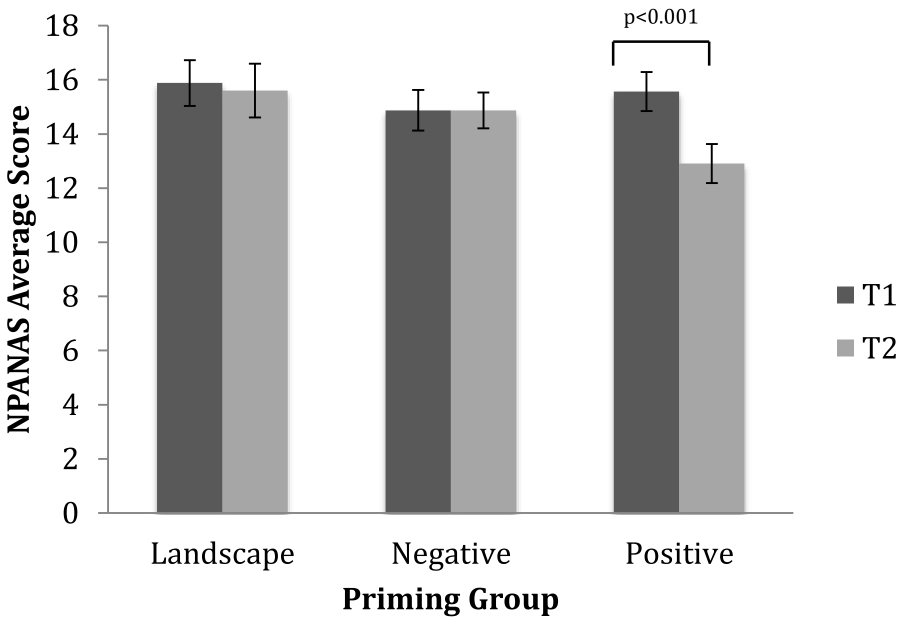


Figure 5.3.3. Comparison of Negative scale PANAS score pre- and post EBA testing

EBA performance

5.3.3. Lag-2 accuracy

As Fig. 5.3.4 illustrates, the control (landscape filler/non-primed) group achieved a relatively high degree of accuracy (approximately 70% correct responses), irrespective of the distractor type. Similar accuracy levels were evident for the negative priming group with both neutral and romantic distractors, while the incorporation of food distractors produced a small reduction in accuracy. The data for the positive priming group again show similar proportions of correct responses when streams contained either neutral or romantic distractors. However, as in Experiment 1, for the positive priming group, food distractors produced a very clear reduction in accuracy, so that only about 30% of targets were correctly identified.

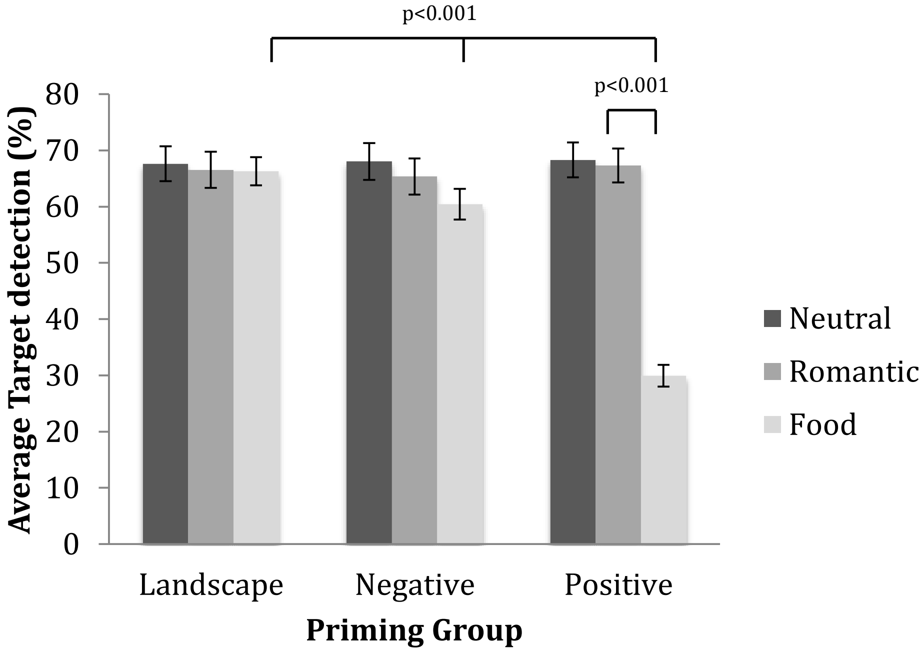


Figure 5.3.4. Target detection accuracy between priming groups under different distractor categories at lag 2

To assess these effects, a factorial ANOVA was performed comparing distractor stream type, with priming group as the between subjects factor. This analysis found marked variation in accuracy between priming groups (F(2,306) = 14.57, $p < 0.001$, partial $\eta^2 = 0.09$), and by distractor type (F(2,306) = 30.92, $p < 0.001$, partial $\eta^2 = 0.17$). These factors were also found to interact to influence performance on target detection (F(4,306) = 17.03, $p < 0.001$, partial $\eta^2 = 0.18$). Tukey HSD comparisons revealed performance under positive priming to be significantly different from landscape ($p<0.001$) and negative priming ($p<0.001$) for streams with food distractors. Performance on streams with neutral or romantic distractor types was not found to differ between priming groups. The respective mean (± SE) percentages of correct responses following food distractors on lag 2 for each priming group were: Landscape 66.31 ± 3.11, Positive 29.94 ± 1.62 and Negative 66.31 ± 3.11.

5.3.4. *Lag-2 reaction times*

Analysis of reaction times revealed no influence of emotional priming condition (F(2,306) = 0.37, p = 0.69, partial $\eta^2 < 0.01$), or distractor type (F(2,306) = 0.03, p = 0.97, partial $\eta^2 < 0.001$), and consequently no interaction (F(4,306) = 0.11, p = 0.98, partial $\eta^2 = 0.001$).

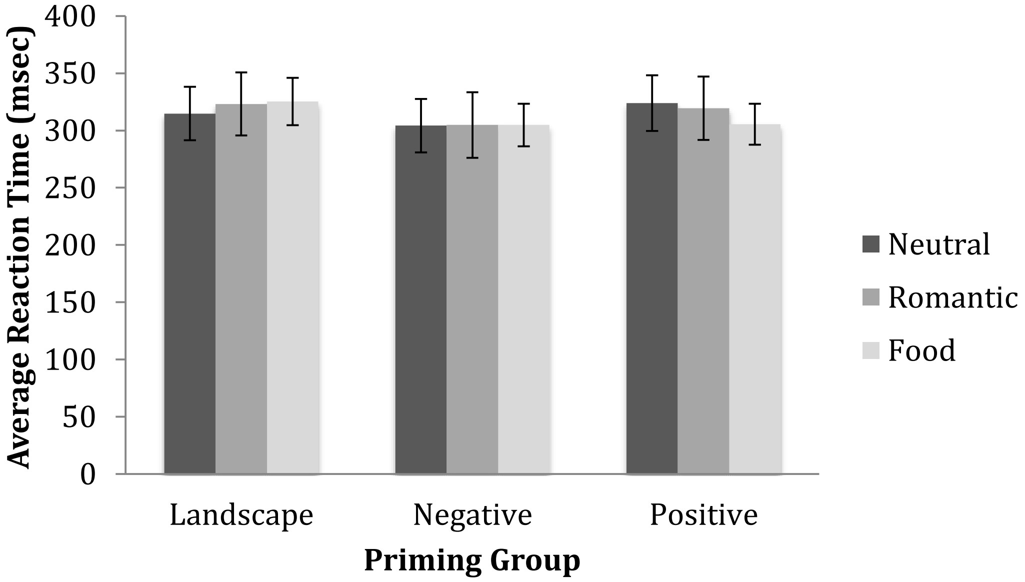


Figure 5.3.5. Reaction times for each priming groups for streams with different distractor categories at lag 2

5.3.5. *Lag-4 accuracy*

As may be seen in Fig. 5.3.6, the control (landscape/non-primed) group again achieved a high degree of accuracy (approximately 75% correct responses), irrespective of the distractor type. As with lag-2, factorial ANOVA revealed significant effects of priming group (F (2,306) = 18.12, p <0.001, partial $\eta^2 = 0.11$), and distractor type (F (2,306) = 11.58, p <0.001, partial $\eta^2 = 0.07$). Priming and distractor type were not found to interact (F (4,306) = 7.10, p <0.001, partial $\eta^2 = 0.08$).

Again, the incorporation of food distractors led to a marked reduction in target identification after positive emotional priming, with accuracy in trials with food distractors for this group being lower than for either neutral or romantic streams (see table 5.3.1. for post-hoc comparisons). No effect of food distractor was evident in either the landscape or negative priming conditions, and romantic distractors had no effect in any priming condition.

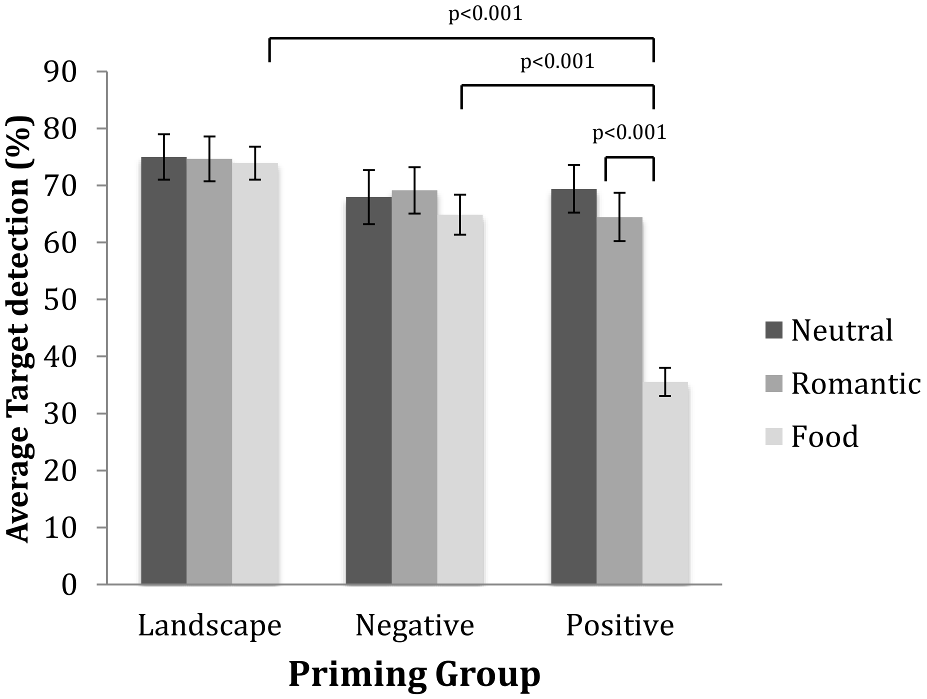


Figure 5.3.6. Target detection accuracy between priming groups under different distractor categories at lag 4

5.3.6. Lag-4 reaction times

Analysis of reaction times for 4-lag data revealed no effect of priming condition (F (2,300) = 0.001, p = 0.99, partial $\eta^2 < 0.001$) or distractor type (F (2,300) = 0.18, p = 0.84, partial $\eta^2 = 0.001$).

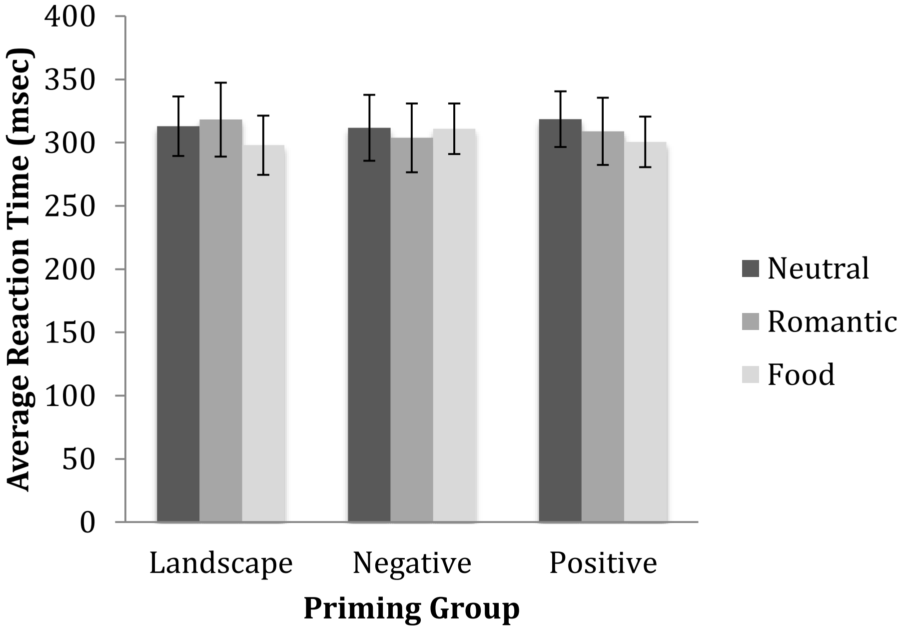


Figure 5.3.7. Reaction times between priming groups under different distractor categories at lag 4

5.3.7. Valence

Analysis of valence ratings showed a large difference between values for the different image categories (F(5,606) = 100.98, p = <0.001, partial η^2 = 0.45), but no reliable influence of priming group (F (2,606) = 1.46, p = 0.23, partial $\eta^2 < 0.01$). More specifically, both food (t(103) = 5.50, $p <$ 0.001, $r = 0.48$) and romantic distractors (t(103) = 8.67, $p < 0.001$, r = 0.65) were rated more highly than neutral. Ratings for food and romantic distractors did not differ significantly (t(103) = 0.68, $p = 0.50$, $r = 0.07$).

Negative priming images were rated more highly than both positive (t(103) = 16.08, $p < 0.001$, $r = 0.85$) and standard, primes (t(103) = 18.16, $p <$ 0.001, $r = 0.87$). Ratings of positive and standard primes not differ from each other (t(103) = 0.26, $p = 0.80$, $r = 0.03$), despite having very different influences on attentional processing of food images.

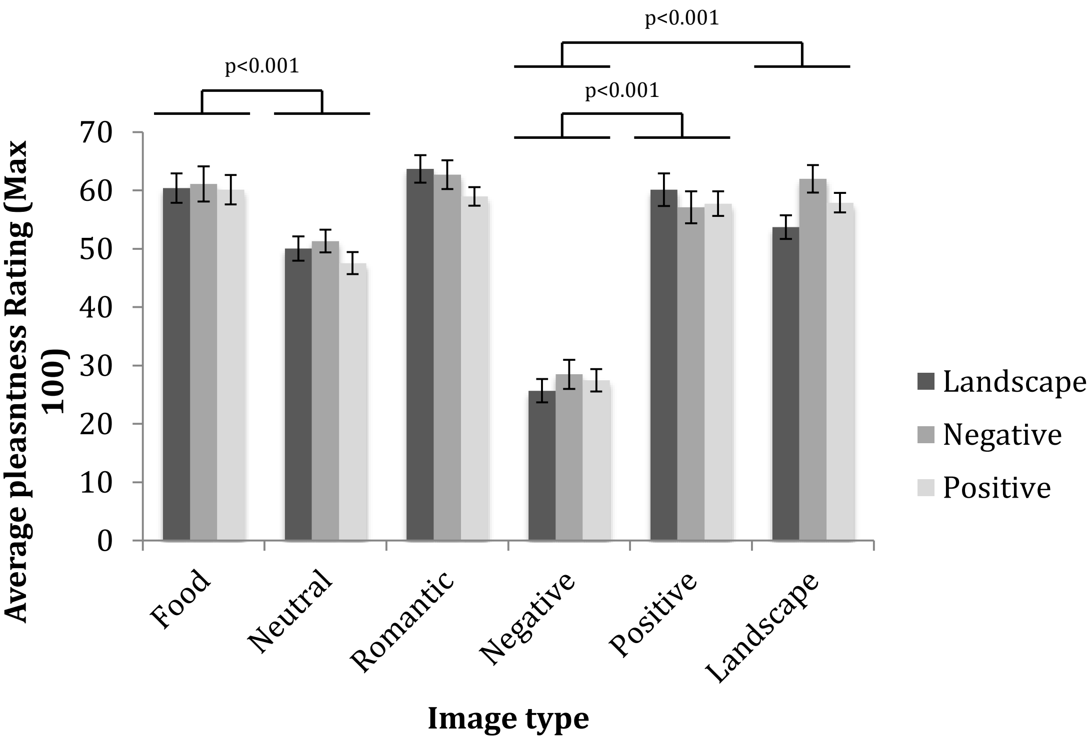


Figure 5.3.8. Comparison of average valence ratings of images between priming groups

5.4. Discussion

This experiment builds on growing evidence demonstrating that motivational and affective neurocognitive systems interact to influence attentional orientation. Specifically, we demonstrate that the affective information received from environmental contexts can enhance the salience (hedonic-value) of motivational objects, such as food. Essentially affective information seems to bias attentional processing towards motivational stimuli, specifically food, after positive affective priming, despite lack of a motivational need (Hunger). While previously research has shown that changes in hunger, lead to changes in affective state (Killgore & Yurgelun-Todd, 2006; Maridakis, Herring, & O'Connor, 2009), a finding reflected in chapters 3 and 4. Research has less commonly investigated and demonstrated the influence of bottom-up changes in affective state on motivational processing. The research conducted here has shown that positive affective primes enhanced the ability of food to cause attentional blindness. Moreover, by using separate groups for the different priming conditions, that effect was amplified and shown to be particular to positive emotional imagery. This replication supports the supposition of affective neuroscience suggesting that affective information plays a crucial role in regulating motivational values (Berridge et al., 2009; Berridge & Kringelbach, 2008; Reynolds & Berridge, 2008), therefore influencing attentional allocation (Berridge & Kringelbach, 2008; Frijda & Sundararajan, 2007; Reynolds & Berridge, 2008; Yantis, 2000; 2005).

A fundamental feature of motivational states, is that deficits - i.e. hunger, promote reductions in positive affect and changes in attentional processing which guide individuals towards remedies of *extremis*. These remedies are often objects of evolutionary importance that aid survival and propagation of genetic material. However, the ancestors of *Homo sapiens* and even our more recent antecedents did not have free access to large quantities of food, and would therefore need to take advantage of the environment, when the opportunity presented itself. Schwarz (1994) suggested that affective information obtained from the environment may provide information about the safety and nature of an individual's surroundings. Affective information is known to play a crucial role in decision-decision making when information is complex by providing a valuing system that simplifies the vast quantity of information (Clore & Huntsinger, 2007; Isen, 2001). However, most research has focused on internally generated affect arising from assessing the external world, while other internal generation of affect relative to food come from deficits (Maridakis et al., 2009) or satiation (see chapters 3 and 4) such as those related to food consumption. However, external affective cues (bottom-up) may tell us when an environment may be taken advantage of or not (Clore & Huntsinger, 2007; Dreisbach & Goschke, 2004; Isen, 2001; Isen & Reeve, 2006). Hence the findings here mirror these principles, demonstrating that positive affect may be used to influence the salience, and therefore selection, of emotive stimuli such as food. Although research has not previously investigated the effects of affective priming on motivation, previous research has investigated the influence of positive affect on food consumption. Research by Bongers et al (Bongers et al., 2013) has previously demonstrated that inducement of positive affect may encourage food consumption. Using a the single target implicit test of association Bongers et al (2013) found that emotional eaters, as defined by DEBQ, ate more after positive mood induction than after negative. Speculatively, positive emotional inducement may moderate the hedonic value/salience of food.

Positive affective priming was found to influence attention towards food more than negative or neutral/standard primes, while negative priming was not found to enhance attentional processing of either food or romantic images more so than neutral/landscape priming. Generally, affective processing is considered to influence attentional selectivity towards emotionally rewarding stimuli, such as erotica and food because they relieve or reduce negative affect (Bongers et al., 2015; Dingemans, Martijn, van Furth, & Jansen, 2009; Evers, de Ridder, & Adriaanse, 2010; Wallis & Hetherington, 2009). Furthermore, contemporary literature has regularly reported inducement of negative affect to increase attention towards food (Bekker et al., 2004; Hepworth et al., 2010; Willner et al., 1998) and responsiveness (pleasure seeking) (Canetti, Bachar, & Berry, 2002a; Macht, 2008). However, research into the influence of negative affect on attentional processing of food has been inconsistent. Specifically, a number of experimental studies have made contrary findings, including the aforementioned study conducted by Bonger et al (2013), which have discovered that negative affective priming does not influence food intake (Bongers et al., 2015; Evers et al., 2010; Wallis & Hetherington, 2009), suggesting that negative affect does not consistently influence appetitive processing. Our findings support the latter studies. Overall, the suppositions of these previous findings, and the present study are that negative affect does not impact attentional processing of food.

The differences in the influences of the two types of affect has been explored previously in implicit studies, with Dreisbach and Goschke (Dreisbach & Goschke, 2004) finding that positive priming promoted cognitive flexibility at the cost of task (cognitive switching test) performance perseveration resulting in increased distractibility. Specifically, Dreisbach and Goschke (Dreisbach & Goschke, 2004) found moderate stimulation of positive affect induced by brief presentations of affective images to have a dramatic effect on the ability of participants to switch and disengage from a previous task-relevant stimulus to a new category. However, inducing negative affect had no influence on the task switching task, reflecting the findings of the present experiment. According to Fiedler (Fiedler, 2012), the dichotomous performance results from distinct cognitive differences between affect types: positive affect encourages exploration, while negative affect incites avoidance of mistakes thus promoting greater focus or analytical processing. Specifically, Fiedler (2001) theorises that positive affect modulates the balance between an accommodative and assimilative processing style. The accommodative style, induced by negative affect, conserves input information. The assimilative processing style, induced by positive affect, analyses incoming information relative to existing knowledge. Despite lexical differences, Fiedler's assumption links well with the present notion that affective information may modulate processing of the environment. However, it does not distinguish between the types of stimuli available, as it does not consider the influence of motivational processing and incentive salience. Consideration of the role of incentive salience within Fiedler's framework would suggest that motivationally relevant images receive increased attention as a combined result of the influence of positive affect on environmental processing and salience attribution.

These findings support the expectations of the neurocognitive literature, in general, which has argued that reward systems and affective systems are combined (Berridge & Kringelbach, 2008; Custers & Aarts, 2005; Grabenhorst & Rolls, 2010; Isen & Reeve, 2006; Panksepp, 2011b; Toates, 2006). However, despite the use of affective induction procedures (priming), the EBA task had no influence on explicit self-reports of affect (PANAS scores). This implies that affective priming with implicit methods may not result in conscious changes in affective state, although affective information clearly had an influence on cognitive processing. However, as suggested by Berridge and Kringelbach (Berridge & Kringelbach, 2008) and Winkielman (Berridge & Winkielman, 2003; Winkielman, 2005; Winkielman & C Berridge, 2004), individuals are often unaware of emotive influences at an implicit level.

A secondary unexpected finding of the study was that food did not capture attention to a greater degree than neutral distractors. The findings of the experiment are to some degree contrary to the literature (di Pellegrino et al., 2011; Piech et al., 2010), which demonstrate that food captures attention more than neutral stimuli. However, Nummenmaa et al (Nummenmaa et al., 2011), have argued that individual variation between participants may influence attention towards food, specifically they found that attention towards food was higher in individuals with higher body mass index scores, compared to lower scores (<25). So, while individuals are generally more attracted to food than others stimuli, this may depend on individual variation. In addition, the type of food being observed is a factor in attentional allocation in a visual search task (Nummenmaa et al., 2011). Previous findings have also shown that romantic imagery presented in an EBA task may also (Most et al., 2007) increase attentional blindness on the EBA task. However, both of these task stimuli utilised images from the IAPS database, which uses out-dated imagery. Recently, Prause et al (Prause, Janssen, & Hetrick, 2007) have suggested that IAP images be updated, particularly as the romantic images are ambiguous on rapid presentation tasks used in implicit research.

In terms of current limitations and future research, several aspects can be acknowledged. These may include the participants' traits, such as sensitivity to reward as measured by emotional eating questionaires. These data were not collected, and it would be interesting to investigate the role of factors such as reward sensitivity and inhibition of reward on attentional processing within the present paradigm. Finally, previous research has shown that appetitive state influences attention to food (Mohanty, Gitelman, Small, & Mesulam, 2008; Piech et al., 2010; Placanica et al., 2002), with less attention given to food when participants are sated compared to fasted. As changes in motivation and positive affect are now known to influence attention towards food, it is suggested that future investigations test the influence of affective priming after satiation.

In summary, the present study supports the neurocognitive literature that suggests that affective and motivational systems interact to influence attentional processing of motivational stimuli, and reflects our previous study demonstrating that positive imagery enhances attention towards food, while negative priming was not a significant influence on participants' attentional processing of food-related stimuli. Overall, this difference may be explained by the difference in how affective information influences cognitive processes, as mentioned by Fiedler, Winkelman, and Berridge (Fiedler, 2012). Of equal importance was the finding that, contrary to previous findings, individuals who are not hungry do not display a continuous alertness to food-related cues within this session exposure, attentional blink paradigm.

Table 5.3.1. Target detection accuracy under lag 4 streams: between priming groups and distractor types (% correct responses)

			Mean ± SD		Statistics	
Distractor	Prime 1	Prime 2	Distractor 1	Distractor 2	t-value	*p-value*
Neutral	Landscape	Negative	67.62 (18.42)	68.03 (18.13)	-0.09	0.93
Neutral	Landscape	Positive	67.62 (18.42)	68.31 (15.47)	0.17	0.86
Neutral	Negative	Positive	68.03 (18.13)	68.31 (15.47)	-0.07	0.95
Romantic	Landscape	Negative	68.03 (18.03)	65.36 (18.16)	0.26	0.80
Romantic	Landscape	Positive	65.36 (18.16)	67.32 (16.85)	0.18	0.85
Romantic	Negative	Positive	65.36 (18.16)	67.32 (16.85)	-0.47	0.64
Food	Landscape	Negative	66.31 (18.40)	60.42 (17.00)	1.36	0.18
Food	Landscape	Positive	66.31 (18.40)	29.93 (9.97)	10.62	<0.001
Food	Negative	Positive	60.42 (17.00)	29.93 (9.97)	9.32	<0.001

Table 5.3.2. Target detection accuracy under lag 4 streams: between priming groups and distractor types (% correct responses)

			Mean ± SD		Statistics	
Distractor	Prime 1	Prime 2	Distractor 1	Distractor 2	t-value	*p-value*
Neutral	Landscape	Negative	75.00 (23.48)	67.97 (22.21)	1.53	0.21
Neutral	Landscape	Positive	75.00 (23.48)	69.41 (17.84)	1.15	0.25
Neutral	Negative	Positive	67.97 (22.21)	69.41 (17.84)	-0.30	0.76
Romantic	Landscape	Negative	74.64 (28.03)	69.14 (22.89)	0.88	0.38
Romantic	Landscape	Positive	74.64 (28.03)	64.47 (21.66)	1.74	0.09
Romantic	Negative	Positive	69.14 (22.89)	64.47 (21.66)	0.88	0.38
Food	Landscape	Negative	73.93 (24.70)	64.84 (23.85)	1.53	0.13
Food	Landscape	Positive	73.93 (24.70)	35.53 (15.25)	8.06	<0.001
Food	Negative	Positive	64.84 (23.85)	35.53 (15.25)	6.22	<0.001

Chapter 6:

Affective Motivation: Investigating the impact of positive affective priming on attentional processing following satiation

6.1. Introduction

Evolution and consequences of gene survival have led to the development of neuropsychological systems that energize an organism's behaviour towards items that promote those goals. As a consequence, motivational systems have evolved which guide the individual toward food in a state of hunger. The motivation to seek and consume food involves complex interactions between motivational, attentional and emotional systems (Panksepp, 1998; Goetz et al., 2008; Gable et al., 2010). Visuo-attentional systems in particular have been found to exhibit considerable preparedness to detect rewarding stimuli, such as food over non-foods (Nummenmaa et al., 2011).

An important aspect of motivation is incentive salience, which is the notion that experiences with stimuli that promote gene survival are naturally rewarding. As a result any behaviours that enhance the opportunity to obtain and consume food are endogenously rewarded. When we are in energy deficit/hungry, incentive salience theory suggests that we are energised towards behaviour to seek out rewards that alleviate that deficit or aversive motivational state (Berridge et al., 2009; Berridge & Robinson, 1998; T. E. Robinson & Berridge, 1993). This 'wanting' process results in food becoming more attractive or rewarding, and therefore more salient than when an individual is sated. Current neurocognitive literature supports this by showing that hungry individuals display stronger attentional biases towards food-related stimuli than when they are sated; an effect that is apparent in visual-probe and eye-tracking studies (Mogg et al., 1998; Placanica, et al., 2002; Castellanos et al., 2009; Nijs et al., 2009; Loeber et al., 2013) and stroop tasks (Channon and Hayward, 1990; Lavy and van den Hout, 1993).

The salience of motivational stimuli may also be investigated by studying temporal changes in attentional processing. This has been demonstrated in studies using techniques that present task-irrelevant, but salient images that can induce an attentional blink, which reduces an individual's ability to detect a specific target presented shortly afterwards within a RSVP (Most, 2012) McHugo et al., 2013). Recently, Neimeijer et al. (Neimeijer et al., 2013) discovered, using RSVP tasks with images of highly palatable foods as distractors, that food cues can elicit an attentional blink. These findings indicate that food and related stimuli gain preferential access to cognitive processing. Furthermore, research has also shown that the preferential allocation of attentional resources may be modified when the salience of food stimuli is enhanced by changes in appetite. Utilising the Emotional Blink of attention (EBA) paradigm, which makes use of RSVPs, Piech et al (Piech et al., 2010) reported that food images had a greater chance of causing attentional blindness when participants were fasted as opposed to sated. Interestingly, this effect was observed despite participants being offered monetary incentives for the performance strength of the target identification; providing further evidence that hunger can involuntarily bias perception even when participants are motivated against it.

The majority of work showing that hedonic value ('liking') and motivational state ('wanting') influence responses towards food have focused on internalized change in motivational processing: i.e., hunger leads to greater attention to food; satiation leads to reductions in attention and 'pleasantness' ratings of food (Brondel et al., 2006). Environments, however, provide large quantities of information, which inform evaluations of when and how to respond. In order to deal with this information surfeit, organisms have developed affective systems that simplify this information to influence our actions or decisions at explicit (Isen & Reeve, 2006) and implicit levels (De Houwer et al., 2009). Furthermore, research shows that neurocognitive motivational and affective systems are strongly interconnected (Berridge et al., 2009; Panksepp, 2011b; E. T. Rolls, 2013; Toates, 2006). Additionally, neuroimaging studies finding that affective information may regulate attentional processing (Carretié et al., 2001; Vuilleumier, 2005).

Particular evidence from experiments with food stimuli indicates that fluctuations in affective state may alter the motivation to eat (Macht, 2008). However, the current literature investigating appetitive and affective processes has largely focused on the influence of negative affect. Generally, studies inducing negative affect find increased reward value for comfort foods as a result of their potential to provide relief from a negative state; essentially acting through negative reinforcement (Baker et al, 2004; Willner et al., 1998). While other studies investigating attentional processes have found that influencing negative affect increases attentional selection of food images in a visual-probe task (Hepworth et al., 2010). Hepworth et al (2010) argued that negative affect increases food's hedonic value resulting in increased salience. It should be noted, however, that an eye-tracking study by Werthmann et al (Werthmann et al., 2014) was unable to replicate this finding. The influence of induced positive affect on eating motivation has rarely been investigated. The few studies investigating the influence of positive affect on appetite have no consensus with some studies reporting increases in appetite (Macht et al., 2002; Evers, et al., 2009; Evers et al., 2013), and others decreases (Turner, Luszczynska, et al., 2010), or no influence on either appetite or food consumption (Lowe & Fisher, 1983; Yeomans & Coughlan, 2009). However, the common theoretical position is that positive affect may have a generalised action to bias attention towards rewarding stimuli and facilitate the acquisition of desirable goals (Tamir & Robinson, 2007). After inducing a positive mood in participants, Tamir and Robinson (2007), found positive affect to promote the orientation of attention towards rewarding words in dot probe tasks. More recently, we have conducted two studies that investigated the influence of positive priming in the EBA paradigm on attentional processing of food: both studies showed that attention to motivational stimuli, including food is enhanced by positive priming.

Considering the aforementioned evidence, it is clear that an attentional bias for food exists innately even in the absence of need. And, notably, emotion inducement has an influence on this attention to food. Furthermore, induced positive affect may increase attention to food. We might therefore expect that manipulation of affective state would also have some impact upon the specific ability of food to capture attention, even following food consumption when – as we have seen earlier, satiation on a specific food leads to images of that food being less distracting than before consumption. In this experiment we investigated whether postprandial positive priming within the EBA task could attenuate the sensory-specific reduction in attention to representations of a food that has been eaten.

6.2. Method

6.2.1. Participants

Twenty-nine normal weight participants (11 males; BMI = 22.76 ± 2.10, 18 females; BMI = 22.28 ± 2.37) aged between 18 and 40 years (male=20.55 ± 2.11; female=21.44 ± 5.32) with normal or corrected-to-normal vision were recruited through the University of Liverpool announcement system. Participants were required to be non-smokers, non-dieters and habitually consume lunch. Exclusion criteria included food intolerances, allergies, and medication influencing appetite or attention.

Participants were informed that the study was investigating changes in attention to motivationally significant stimuli over time; no specific reference was made to our central focus on attention towards food and positive priming relative to appetitive state. Financial compensation was given for participation in experiment and time given. The University of Liverpool's

Institute of Psychology, Health and Society Ethics Committee gave ethical approval for the study.

6.2.2. *Emotional Blink of Attention Task*

The study utilized an adapted version of the emotional blink of attention (EBA) paradigm (see Piech, Pastorino & Zald (2010), as described in a previous chapter. This task consists of several trials, each trial rapidly presents a stream of several images (RSVP), participants were required to detect a target image from the rapid visual stream. The EBA task was presented on a laptop using E-Prime 2.0.242.

Each visual stream, comprised of 17 images presented consecutively without breaks between presentations. Images in the stream serve one of three functions:- filler, distractor, or target (see figure 6.2.1). Each image in the stream was displayed for 100ms, with no interval between presentations of successive images.

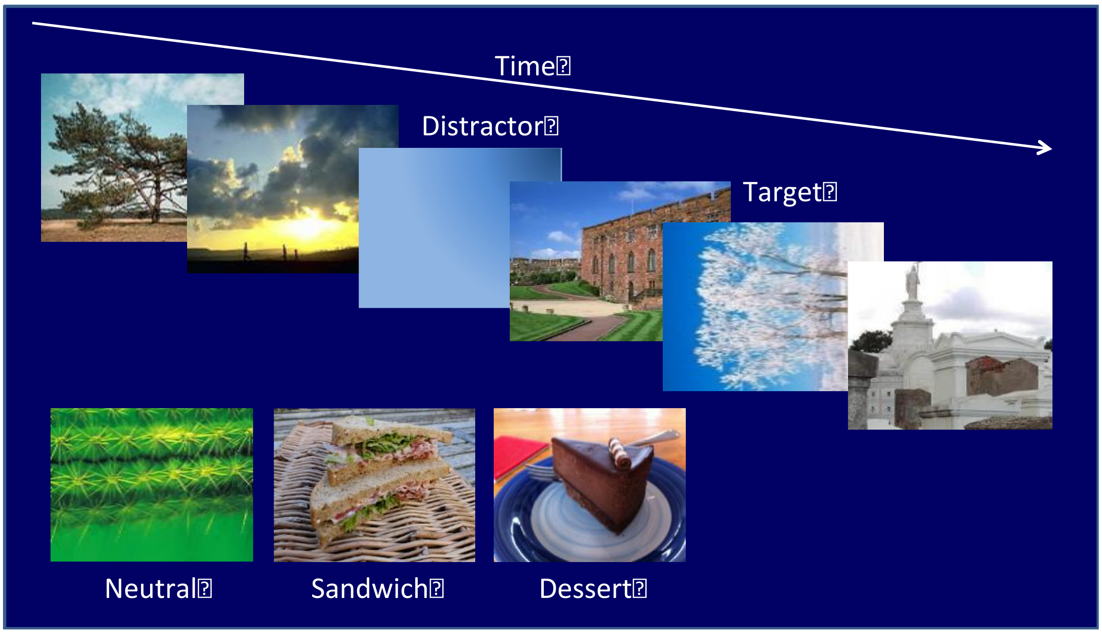


Figure 6.2.1. Diagram of EBA rapid visual streams with landscape/standard fillers, neutral priming condition

Distractor (neutral, dessert or sandwich) could appear at any point within the visual stream after the first three filler (landscape or positive emotional) images had been displayed, and before the last two. Target images were displayed 200 ms after the onset of the distractor (2-lag). At the conclusion of each stream participants were required to indicate, in response to questions appearing on the screen, whether they had seen the target and whether it was rotated 90° to the left or right, regardless of the response to the first question. Participants were instructed to answer each question as quickly as possible. Only trials for which the participant reported seeing the target and correctly indicated its rotation were taken as correct responses. The program recorded reaction times to the questions, and response accuracy.

Table 6.2.1. Schedule of testing

Time (min)	PANAS	AVAS	EBA	Valence	Lunch
0	▨	▨	▨		
20					
40	▨	▨	▨		
60					
80	▨	▨	▨	▨	
100					▨
120	▨	▨	▨	▨	

AVAS = Appetitive Visual Analogue Scale, PANAS = Positive Affect Negative Affective, EBA = Emotional Blink of Attention, Valence = Valence Scale, Lunch = Time which participants are given food. Grey = tested in time period. Note EBA at 120 includes positive priming.

The experiment comprised 4 test sessions (see table 6.2.1. for a schedule). In the first 3 test sessions, participants were exposed to an EBA task with 3 blocks of 40 streams (120 trials in total) in each session, with a 30-second interval between successive blocks. All rapid visual streams of the EBA task administered in the first 3 sessions contained landscape/standard fillers, and were used as the non-affective trials (see Fig. 6.2.1.). In the final testing session, which incorporated positive priming (see Fig. 6.2.2.), the EBA task consisted of 6 blocks of 40 streams, 240 RSVPs in total. The different distractor categories: neutral, dessert, and sandwich images, were distributed both randomly and equally within each block, in all testing session. In the fourth test session, streams were distributed in blocks with either Landscape/ standard (non-affective condition) only or positive fillers only (positive affect condition), with distractor categories again distributed randomly and equally within each block. In total 240 RSVPs were split between 6 blocks of 40 RSVPs containing half standard/landscape fillers and the other half positive primes/fillers. Distractors were once again randomly but equally distributed. All images were taken randomly from their respective image banks.

Figure 6.2.2. Diagram of EBA positive priming RSVP used in post-prandial task

6.2.3. *Visual stimuli*

A total of 854 colour, luminance-matched, photographic images were used, each presented on screen in a 95 mm wide x 75 mm high format, viewed at a distance of approximately 500 mm. Images were taken from the International Affective Picture System (IAPS) databank (Lang, Bradley & Cuthbert, 2001), supplemented by photographs of food prepared specifically for this study. The fillers were selected from 252 images of landscapes and urban scenes. The targets were drawn from separate banks of similar scenes rotated either 90° to the left (136) or right (135). Neutral distractors were 48 images selected from the IAPS, depicting commonplace objects or scenes and chosen for their low arousal and neutral valence ratings. Food distractors belonged to one of two categories: sandwich or dessert images. Fifty sandwich images represented the particular sandwich type (ploughman's or BLT) that each participant had selected to eat for their lunch, taken from a range of different perspectives with the filling being easily identifiable in each. Dessert distractors were drawn from 150 photographs of cheesecake matched for the background and luminosity.

6.2.4. Procedure

Participants were required to attend the laboratory at 10:50 for preliminary screening to ensure compliance with inclusion criteria, and provide written informed consent prior to participation. Participants were not given any specific instructions about eating before study participation, other than being told that bringing food and drink into the laboratory environment was prohibited. Prior to the study participation, participants were asked to select their preferred sandwich type to consumed from a choice of two types:- Ploughman's or Bacon, Lettuce and Tomato (BLT). Sandwiches were obtained from a national supermarket chain. Participants were required to remain within the laboratory area for the duration of the experiment. Between testing sessions, participants were allowed to relax in a lounge area with access to computing facilities and the internet, along with a range of reading material and a television.

Initially, participants completed the Positive Affect Negative Affect Scale (PANAS; Watson, Clark & Tellegen, 1988) and an appetite visual analogue scale (AVAS; adapted from Blundell et al, 2010). The PANAS requires participants to rate their level of mood on 20 traits between the anchored terms 'Not at all' and 'Extremely' on a 100mm visual analogue scale i.e. energised, alert, sad, tired etc. While the AVAS assess motivation to eat and comprises of comprises 4 appetite-related items ('How hungry do you feel?', 'How strong is your desire to eat?', 'How full are you', and 'How much food do you think you could eat'). The AVAS also utilised a 100 mm VAS anchored with the terms 'Not at all' and 'Extremely', to record responses to each item. A single AVAS score was derived from the average rating of the 4 items, with a potential maximum score of 100 indicating the highest level of motivation to eat.

Having completed these initial ratings, participants undertook the first EBA session. Subsequently, over the course of 2 hours and 30 minutes, the AVAS, PANAS and EBA were repeated on 4 occasions, each separated by a 20-minute interval. After 1 hour and 40 minutes from the start of testing (at approximately 12:40), participants were given lunch, comprising their preferred, pre-selected sandwich along with water to drink. Each participant was provided with 2 identical sets of sandwiches, presented on a plate, and were invited to eat as much, or as little, as they wanted until they felt sated. Testing recommenced 20 minutes after lunch was presented, as described above.

Both before and after lunch, participants were asked to complete a valence task, and rate 10 examples of each image type selected at random from their respective image banks: landscape, positive affect, neutral, sandwich, and dessert. Images were rated on a 100 mm visual analogue scale, anchored with the terms “not at all pleasant” and “extremely pleasant”. At the end of the experiment, before debriefing, participants were asked to complete the Dutch-eating behaviour questionnaire (DEBQ) (van Strien et al., 1986). The DEBQ consisted of 33 items that assess three subscales: external eating (10 items; responsiveness to the exposure of food-related stimuli), emotional eating (13 items; assessing food consumption in response to emotion), and dietary restraint (10 items; assessing restrict food intake). Items in the DEBQ utilized Likert 5-point scales how frequency each item was applicable to (1 = never; 5 = very often). Finally participants were debriefed as to the purpose of the study and released from the experiment.

6.2.5. Data analysis

Data were organised into three matrices to assess: variation of each dependent variable at each measurement point; average score changes from baseline (T1), and changes over each successive intervals (Tn – Tn+1). Data were checked for outliers with responses falling outside k=2.2 (see

Hoaglin and Iglewicz, 1987). Skewedness was not corrected, as descriptive statistics did not display any significant violations of parametric assumptions.

Analysis of variance (ANOVA) was used to analyse temporal changes in responses for AVAS, PANAS and valence, and for EBA accuracy and reaction times, with distractor type as the between-subjects factor and test session, and priming as the within-groups factor. *Post hoc* analyses were conducted using the Student's procedure. Relationships within the data were analysed using regression models. Pearson's correlation coefficient was also applied to data to assess covariance between the different variables. Data analysis was conducted with R, using the RStudio software package.

Percentage of correct response was analysed for each distractor type (3) and compared with a factorial ANOVA over session (4) and priming type experienced (2).

6.3. Results

6.3.1. Appetite Scores

Participants reported low to moderate levels of eating motivation before completing the EBA task (T1: mean ± SE = 49.18 ± 3.30). Scores changed considerably over the course of the experiment, with significant increases in appetite between T1 and T3 (Beta = 0.57, (F(1,85)=39.99, $p<0.001$, $AdR^2=0.31$) (see Fig. 6.3.1). Particularly large reductions in appetite were seen between the immediate pre-prandial (T3 = 72.25 ± 1.65) and post-prandial sessions (T4: 19.28 ± 2.48) as reported on the AVAS ($t(58) = 18.68$, $p < 0.001$, $r = 0.93$). There was no gender difference in the levels of hunger motivation (F(1,170) = 0.35, $p = 0.55$, partial $\eta^2 = 0.01$). On average, participants consumed 313.32 ± 12.49 g (662.06 ± 26.36 kcal).

p<0.001 p<0.001 p<0.001

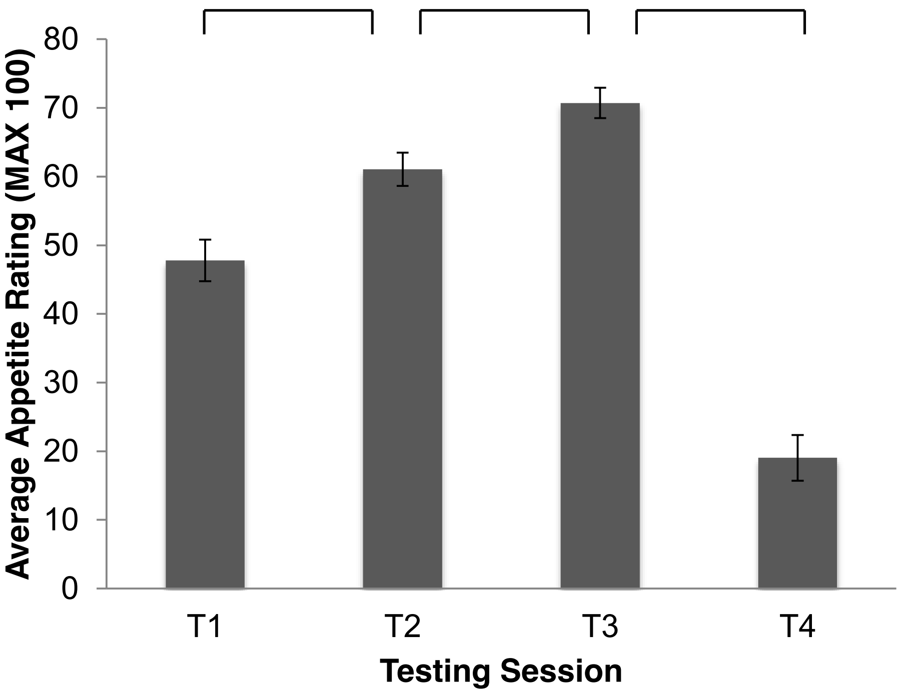


Figure 6.3.1. Average AVAS of each testing session

6.3.2. *Positive Affect*

Analysis did not reveal any significant changes in responses to the positive scale of the PANAS (PPANAS) over session (F(1,112) = 0.13, p = 0.72, partial $\eta^2 = 0.001$). Average PPANAS scores gradually decreased over the pre-prandial testing sessions: T1 = 58.64 ± 2.47, T2 = 53.81 ± 2.88, and T3 = 50.66 ± 2.91 (Fig. 6.3.2). A regression model significantly accounted for reductions in PPANAS between T1 and T3 (Beta = -0.22, (F(1,85)=4.22, p=0.04, $AdR^2=0.04$). A non-significant trend was observed for a changes in PPANAS pre- (T3: 50.66 ± 2.91) and Post-prandial (T4: 58.21 ± 2.91) (t(56)=-1.83, p=.07, r=0.24). Gender differences in the PPANAS scores were found across testing (F(1,112) = 9.33, p = .003, partial $\eta^2 = 0.08$), but did not interact with session (F(1,112) = 0.56, p = .46, partial $\eta^2 < 0.01$).

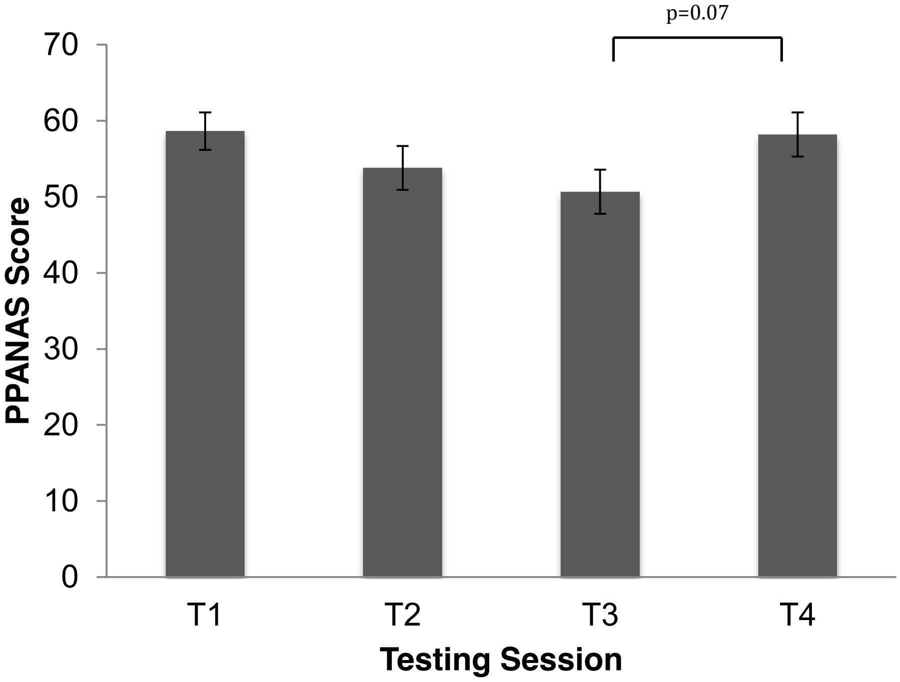


Figure 6.3.2. Comparison of average positive affect score on PANAS across testing session

6.3.3. Negative affect

Significant changes in negative affect (NPANAS) were also observed over the course of testing (F(1,112) = 8.96, $p = 0.003$, partial $\eta^2 = 0.07$). Scores decreased throughout the experiment: T1= 14.82 ± 1.50, T2 = 13.70 ± 1.51, T3 = 12.38 ±1.46, and T4 = 9.11 ± 1.68. A linear model accounted for gradual changes in the negative affect from T1 to T4 (Beta = -0.26, (F(1,114)=8.01, p=0.005, $AdR^2=0.06$). However, there were no significant changes in negative affect between the pre- and post-prandial sessions (t(56)=1.62, p=0.11, r=0.21). Significant gender differences were found (F(1,112) = 15.53, $p < .001$, partial $\eta^2 = 0.08$), with males reporting lower levels of negative affect (9.03 ± 0.97) compared with females (14.62 ± 0.98). However these differences in negative affect did not interact with session (F(1,112) = 3.31, $p = 0.81$, partial $\eta^2 < 0.001$).

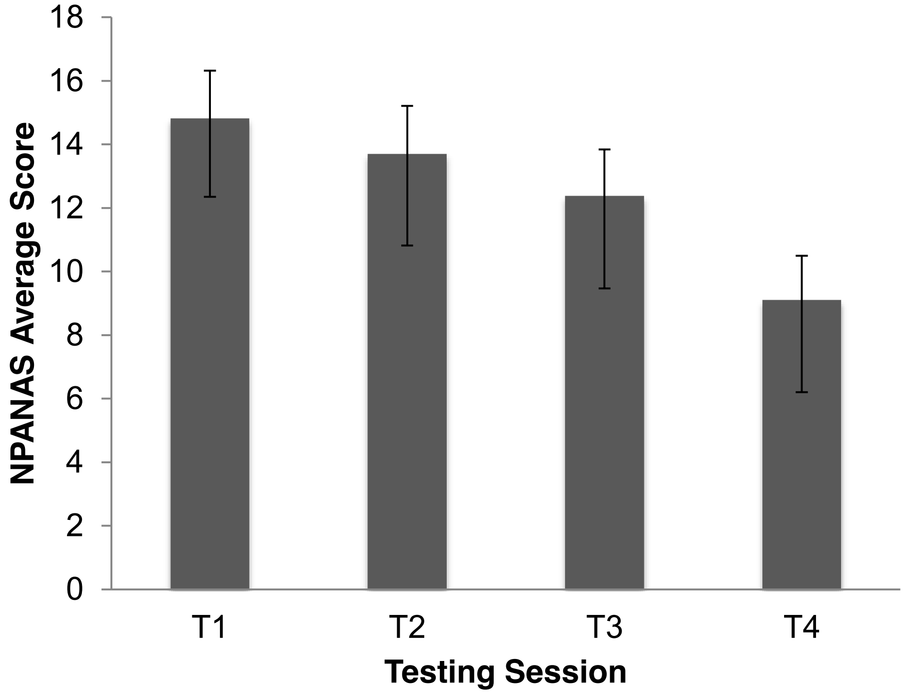


Figure 6.3.3. Comparison of average positive affect score on NPANAS across testing session

6.3.4. EBA accuracy

Initial inspection of EBA task performance revealed an anticipated practice effect between T1 and T2, with task performance improving substantially across all variables. Subsequent analysis therefore used data that was collected from T2, T3 and T4. A factorial analysis of task performance between T2-T4 revealed that distractor type (F(2,414) = 27.88, p<0.001, partial $\eta^2 = 0.15$), priming (F(1,414) = 25.26, p<0.001, partial $\eta^2 = 0.7$) and gender (F(1,414) = 10.24, p=0.002, partial $\eta^2 = 0.03$) had significant influences on the accuracy of target detection in EBA visual streams. Discounting the practice effect removed any influence of time on task performance measures (F(1,414) = 0.06, p = 0.003, partial $\eta^2 = 0.03$). In addition, gender did not interact with session distractor type to influence attentional processing (F(2,414) = 0.02, p = 0.99, partial $\eta^2 < 0.001$).

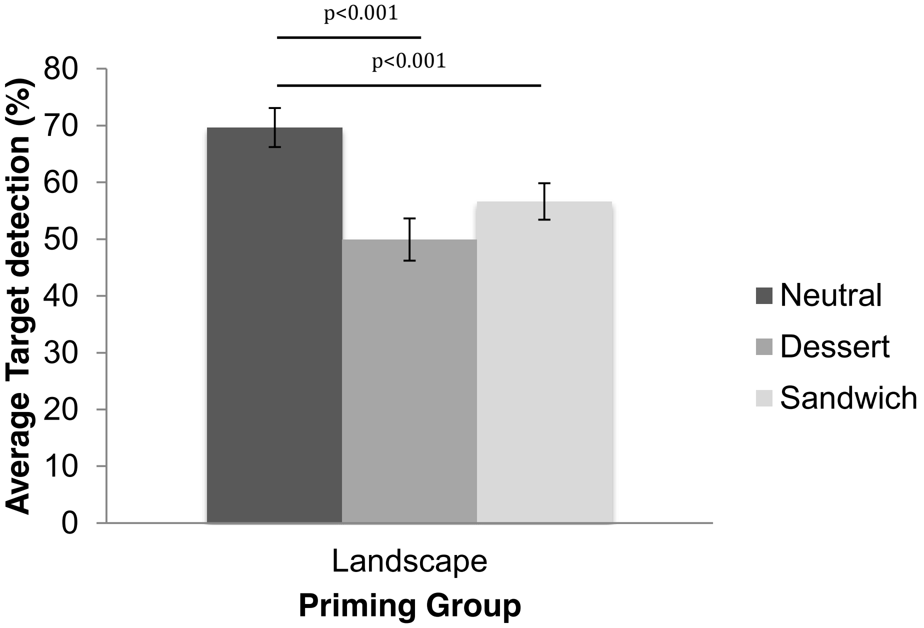


Figure 6.3.4. Comparison of average EBA target detection following each distractor type at T3 (pre-prandial), with no affective priming

Comparisons of accuracy measures before and after lunch revealed no significant changes in attention to dessert (t(28)=-1.21, p=0.23, r=0.22) or sandwich distractors (t(28)= 0.89, p=0.38, r=0.17) with neutral priming, despite large changes in eating motivation. Notably, substantial reductions in postprandial accuracy were produced when positive fillers were paired with each food distractor type compared with non-affective priming at T4: respectively 13% for sandwich (t(28)= 7.77, p<0.001, r=0.83) and 16% for dessert distractors (t(28)= 4.73, p<0.001, r=0.67; see figure 6.3.5). A small but significant reduction in target detection was also observed for neutral distractors in positively primed streams (approximately 4%; t(28)= 2.63, p=0.01, r=0.45).

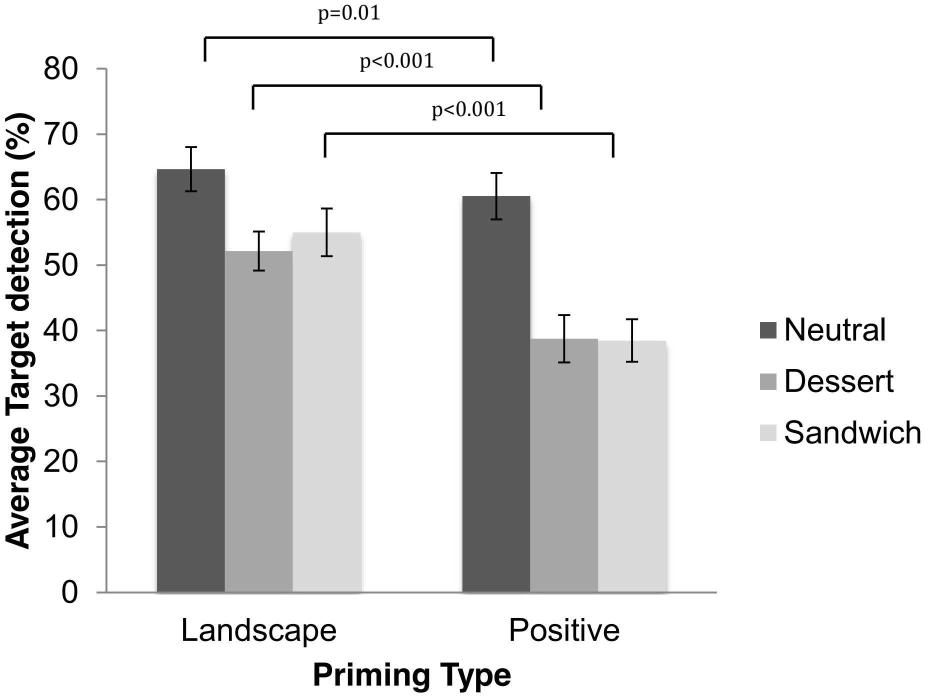


Figure 6.3.5. Comparison of EBA target detection for each distractor type between affective priming conditions after food consumption.

Post-hoc comparisons of target detection within priming groups found under both positive and landscape (non-affective priming) that target detection was lower for both food types see table 6.3.1.

Table 6.3.1. Post-hoc comparisons of target detection accuracy at T4: Within priming groups and between distractor types (% correct responses)

			Mean ± SD		Statistics	
Prime	Distractor 1	Distractor 2	Distractor 1	Distractor 2	t-value	*p-value*
Landscape	Neutral	Dessert	64.66 (18.15)	52.16 (19.05)	5.42	<0.001
Landscape	Neutral	Sandwich	64.66 (18.15)	55.00 (19.53)	4.06	<0.001
Landscape	Dessert	Sandwich	52.16 (19.05)	55.00 (19.53)	-1.74	0.09
Positive	Neutral	Dessert	60.54 (15.74)	38.75 (19.20)	7.34	<0.001
Positive	Neutral	Sandwich	60.54 (15.74)	38.48 (17.33)	8.74	<0.001
Positive	Dessert	Sandwich	38.75 (19.20)	38.48 (17.33)	0.13	0.09

6.3.5. *Reaction times*

Analysis of reaction time for correctly identified targets with 2-lag (Fig 6.3.6) revealed large differences between in reactions times across sessions (F(1,410) = 62.56, $p < 0.001$, partial $\eta^2 = 0.13$) as a result of reduced reaction times over time: T1 = 274.91 ± 6.53, T2 = 240.65 ± 6.83, T3 = 209.06 ± 6.29, T2 = 208.03 ± 4.37. Change in reaction times over time was accounted for by a linear model (Beta = 0.49, (F(1,426) = 75.03, p < 0.001, $AdR^2=0.15$).

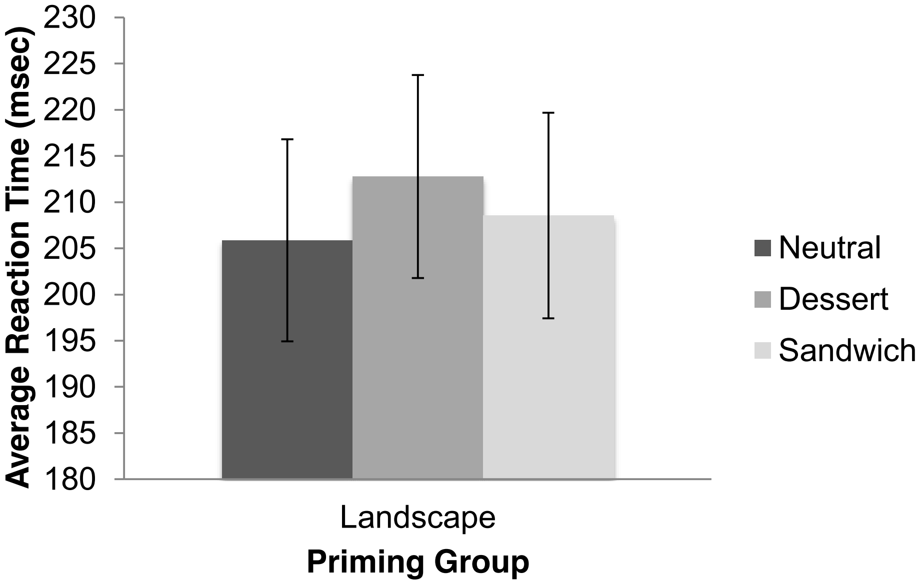


Figure 6.3.6. EBA average reaction times between distractor types at T3

ANOVA also revealed a significant effect for priming sessions (F(1,410) = 12.35, $p < 0.001$, partial $\eta^2 = 0.03$). However, an independent samples t-test investigating RT at T4 (Fig 6.3.7) revealed no significant influence (t(169) = 0.13, p=0.89, r=0.01). An effect was also found for gender (F(1,410) = 5.80, $p = 0.02$, partial $\eta^2 = 0.01$) as a result of males (219.18 ± 5.49 ms) being on average slightly faster to respond than females (233.77 ± 3.72 ms). Gender did not interact with priming or distractor type to influence response times (F (2,410) = 0.09, $p = 0.91$, partial $\eta^2 < 0.001$). Neither did distractor type influence response times (F (2,410) = 0.0, p = 0.96, partial η^2 < 0.001).

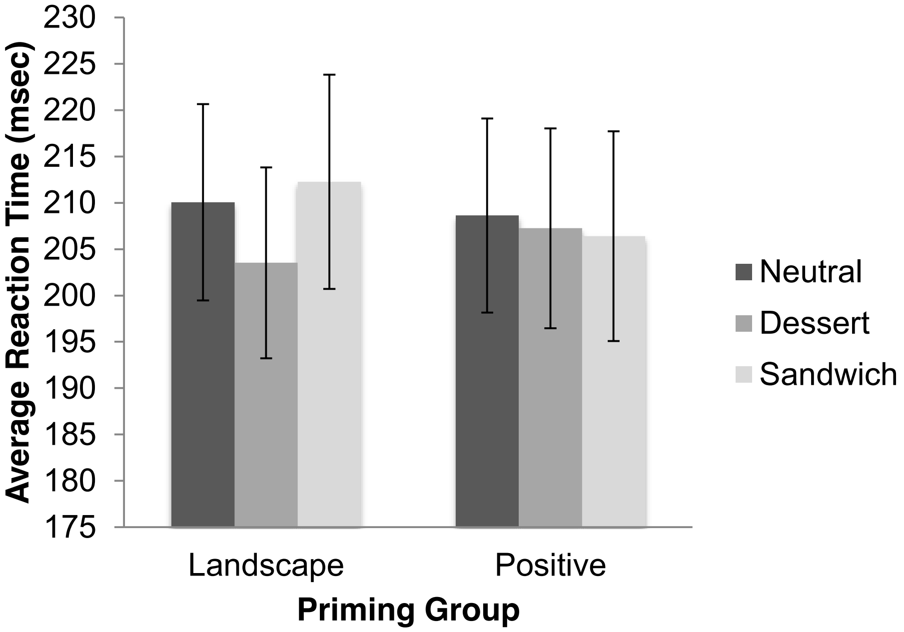


Figure 6.3.7. EBA reaction times of lag 4 streams between distractor types and priming at T4

6.3.6. Valence

Analysis of valence ratings showed a large difference between values for the different image categories (F(4,280) = 11.25, p = <0.001, partial η^2 = 0.14). There was no reliable influence of sex (F (1,280) = 3.65, p = 0.06, partial η^2 = 0.01). Sandwich image rating demonstrated a marked decrease in pleasantness after consumption (t(28) = 5.72, p < 0.001, r = 0.73). Post-hoc comparisons found that landscape fillers were not more attractive than positive images (t(28) = 0.91, p = 0.16, r = 0.26). Neutral images were less attractive than sandwiches before consumption (t(28) = 5.37, p < 0.001, r = 0.71), but not after consumption (t(28) = 0.36, p = 0.72, r = 0.07). Dessert images were significantly more attractive than neutral both before (t(28) = 7.80, p < 0.001, r = 0.83) and after food consumption (t(28) = 6.08, p < 0.001, r = 0.75). Ratings of sandwiches and dessert were not significantly different before consumption (t(28) = 0.40, $p < 0.001$, r = 0.08) but were after consumption, due to the reduced pleasantness of sandwiches (t(28) = 3.37, $p = 0.002$, $r = 0.54$).

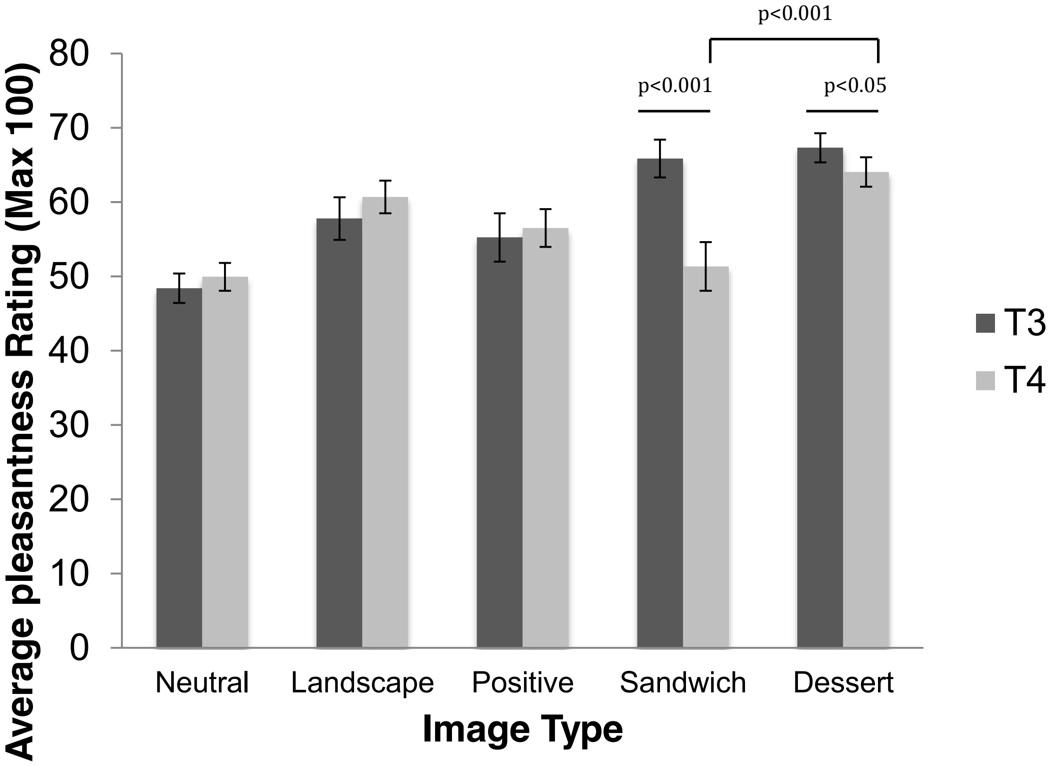


Figure 6.3.8. Comparison of image pleasantness ratings

6.4. Discussion

The present study aimed to investigate both the influence of changes in motivational state (i.e., hunger) and of positive priming on attention to motivational stimuli (i.e., food images). We predicted that satiation on sandwiches would lead to a reduction in the ability of sandwich distractors to capture attention, and that the emotional priming in postprandial testing would reverse that effect. Contrary to previous studies (Chapter 3, di Pellegrino et al., 2011; Piech et al., 2010), we found that attention to food was unaffected following satiation (when considering data from trials without emotional prime images), despite a large reduction in appetite from pre- to post-prandial testing sessions. The absence of an effect conflicts with our earlier findings (chapter 3), in which satiation on sandwiches led to specific postprandial attenuation of the ability of sandwich distractors to capture attention. Additionally, this failure to replicate our earlier finding occurred despite large devaluations in explicit rating of sandwich pleasantness following sandwich consumption. However, as with our previous studies, we did again find that positive priming enhanced the ability of food stimuli to capture attention – in this case, in participants who were sated. Thus, the presentation of emotional images appears to exert a greater influence on attention to food than changes in motivation to eat resulting from actual consumption.

A crucial finding of this experiment was that positive affective information enhanced the ability of food-related stimuli to capture attentional faculties. Essentially, this finding provides further evidence that affective information can influence attentional processes and possibly the hedonic value of motivational stimuli. It is possible that affective information received from environmental contexts enhances the salience, of motivational stimuli, such as food. According to affective neuroscience literature it should be expected that changes in affective systems would influence implicit processing of the environment and salience attribution of motivational stimuli (Berridge & Kringelbach, 2008; Custers & Aarts, 2005; Grabenhorst & Rolls, 2010; Isen & Reeve, 2006; Panksepp, 2011b; Toates, 2006; Winkielman & C Berridge, 2004). According to Isen (Isen, 2001; Isen & Reeve, 2006), the affective system developed out of a necessity to estimate and simplify complex environmental information (Isen, 2001) in order to assess it for safety, which would allow opportunism if safe (Schwarz, 2000). Hence, externally presented affective cues may inform an individual of safety and permit the exploitation of opportunistic events/environments. Previous research with positive priming has shown this to be the case, with the inducement of positive affect promoting food consumption in emotional eaters (Bongers et al., 2013). As a result, positive affective information is considered to influence attentional processing through interactions with the motivational systems, even if individuals are not aware of it (Berridge & Winkielman, 2003; Winkielman, 2005; Winkielman & C Berridge, 2004). However, the extent to which positive priming images presented in this study directly influence affective processing is not directly accessible with the method employed. The data do indicate that positive affective information – even briefly presented – is sufficient to promote attentional processing of beneficial stimuli.

A further feature of the findings is that humans continually display a preparedness for the detection of food, as other studies have found (di Pellegrino et al., 2011; Mogg et al., 1998; Nummenmaa et al., 2011; Piech et al., 2010). While positive priming seemingly enhances this effect, appetitive state was not found to contribute to processing of food related images. Historically research has shown that sweet foods with high baseline valence ratings, such as desserts are less likely to display postprandial declines in pleasantness than other foods (J. Johnson & Vickers, 1992a; Stoeckel et al., 2007; Wansink et al., 2003). Furthermore, recent research by Nummenmaa et al (Nummenmaa et al., 2011) has clearly demonstrated that the palatability of food influences how easily food is detected in a visual search task. While the present experiment supports this to some extent, the same conclusion cannot be applied to sandwiches as the findings of Chapter 3 clearly show that attentional processing of sandwiches was influenced by changes in hunger. This finding warrants further research, as the amount of food consumed, hunger traits or BMI do not account for this finding.

Despite hunger not influencing attentional processing of food related stimuli in this study, it was found to once again influence changes in affective state. A common feature of appetite state is that hunger reduces self-reports of positive affect (Maridakis et al., 2009), which promotes individuals to seek out remedies. Food consumption should therefore reinstate and reductions in affective state. According to Winkielman and others (Berridge & Kringelbach, 2008; Berridge & Winkielman, 2003; Winkielman, 2005; Winkielman & C Berridge, 2004), individuals are usually unaware of these changes in affective state but their behaviour is affected. However, in the present study participants seemed to track these affective changes. This is consistent with previous research which has found that changes in hunger interact with self-reported states of affect, with hunger leading people to feel less positive than when sated (Killgore & Yurgelun-Todd, 2006; Maridakis et al., 2009).

6.4.1. Limitations

A few aspects of the present study may be acknowledged in negatively influencing the findings seen here. Primarily the influence of priming on attention to food was smaller than expected in comparison to the other EBA experiments using priming. The likely cause of this was the randomisation method utilised for postprandial testing, in which all streams (priming and non-priming) were randomly selected by the program. In previous experiments (see chapter 5), priming was segmented into blocks of streams, with distractors randomly distributed within those blocks. This factor may also account for the slight change in attentional processing of neutral streams between priming conditions. It is possible that this could be remedied by use of a between participants design, with one group receiving affective priming group and another control group receiving only non-affective priming.

Finally, it is important to note that we compared two foods that initially did not have large differences in hedonic ratings, perhaps making it more difficult to distinguish between attentional processing of the two types.

Furthermore, in chapter 3 we provided participants with far more stimuli, due to the greater range of sandwiches. However, the most palatable sandwiches were provided to participants to ensure compliance to consume. It is possible, by limiting the food given to the most attractive that we inadvertently reduced the impact of sensory-specific satiety – even though both appetite and pleasantness ratings of sandwiches declined postprandially. While it is important to distinguish between attentional processing of food types, greater consideration should be made for meal choices and therefore stimuli presented (corresponding food images) in the future.

Conclusion

In conclusion, the present study found evidence that affective imagery enhanced the salience of food images, as evidenced by enhanced attentional processing of those stimuli. Presentation of positive emotional imagery again proved effective in increasing attention capture by food images – irrespective of food type. In this instance, however, changes in appetitive state where not effective in reducing attention to the food consumed, suggesting the primacy of emotional factors over eating motivation in attention to food. Confirming previous research, it appears that individuals display a continuous alertness to food-related stimuli that may be enhanced by positive affect independently of changes in appetite.

Table 6.3.2: Target detection accuracy at pre and post prandial testing sessions: Between distractor types (% correct responses)

			Mean ± SD		Statistics	
Prime	Distractor T3	Distractor T4	Pre-prandial	Post-Prandial	t-value	*p-value*
Landscape	Neutral	Neutral	69.66 (18.56)	64.66 (18.15)	2.61	0.01
Landscape	Sandwich	Sandwich	56.64 (17.41)	55.00 (19.53)	0.89	0.38
Landscape	Dessert	Dessert	49.91 (20.11)	52.16 (19.05)	-1.21	0.23
Neutral	Landscape	Positive	64.66 (18.15)	60.54 (15.74)	2.63	0.01
Sandwich	Landscape	Positive	55.00 (19.53)	38.48 (17.33)	7.77	<0.001
Dessert	Landscape	Positive	52.16 (19.05)	38.75 (19.20)	4.73	<0.001

Table 6.3.3: Comparison of target detection accuracy at T4 between priming sessions by distractor types (% correct responses)

			Mean ± SD		Statistics	
Distractor	Prime	Prime	Pre-prandial	Post-Prandial	t-value	*p-value*
Neutral	Landscape	Positive	64.66 (18.15)	60.54 (15.74)	2.63	0.01
Sandwich	Landscape	Positive	55.00 (19.53)	38.48 (17.33)	7.77	<0.001
Dessert	Landscape	Positive	52.16 (19.05)	38.75 (19.20)	4.73	<0.001

Chapter 7: General Discussion

Since the dawn of civilisation philosophers have wondered about and speculated on the nature of motivation and emotion. In present-day environments this intrigue has led investigations of neural activity and its associated behaviour, developing initially from animal studies into modern neuroimaging and cognitive methodology. Current research from these experimental disciplines has resulted in the incentive salience framework. Incentive salience theory has become commonly applied to motivational research and accepted particularly by researchers of addiction. However, this well supported framework/theoretical model has been largely left unattended by cognitive scientists investigating appetite and the motivational processing of food. That is not to say that research has not occurred, but that there is a dearth of literature relative to other fields. However, the lack of research regarding the equally important but often neglected area of affective processing is perhaps even more obvious. Affective processing has often been seen as a 'black box' and ignored despite clear evidence from cognitive neuroscience of its vital role in decision making and assessing our environments (Hermans, Baeyens, Lamote, Spruyt, & Eelen, 2005; see Isen, 2001; Isen & Reeve, 2006; Murphy & Zajonc, 1993).

The initial overarching aims of this thesis were three-fold. Firstly, to explore the influences of fluctuations in motivation on the implicit processing of food. Secondly, to investigate the differences in attentional processing of different food types. And thirdly to investigate the influence of affective processing on implicit processing of food related stimuli. Finally, a fourth goal arose from studies directed at those aims: to investigate the interactions between motivational and affective systems, and how they may influence the implicit processing of food.

In the first chapter, theoretical evidence detailing the neurocognitive systems and learning processes were outlined and related to recent work on implicit processing. The analysis of the area revealed several unresolved issues: i) does implicit processing of food fluctuate in line with motivational state, following the principle of alimentary alliesthesia and/or sensory specific satiety; ii) does attention to food vary depending on its appetitive/hedonic value; iii) does affective state fluctuate in line with motivation, and finally iv) does affective information influence implicit processing of motivational stimuli?

Investigating these questions was necessary for two reasons. Firstly, we sought to advance our theoretical knowledge of motivational and affective processes, and specifically of implicit processing of food-related stimuli, which may contribute to overconsumption. And secondly, to identify interactions between motivational and affective systems, to understand how intrinsic and extrinsic information relating to these systems redirect attentional processing.

7.1. Summary of main findings

7.1.1. Appetitive state and Attentional processing

The central assumption of the thesis was that attention is drawn towards food, particularly in a state of *extremis* or need. Attention given to food should depend on the motivational state of individuals, with the salience of food stimuli caused by ‘wanting’ increasing attention towards food. The first experiment (Chapter Three) of the thesis, attempted to extend and build on the groundwork laid out by Piech et al (Piech et al., 2010). As previously mentioned, the EBA design had been found to detect changes in attentional processing of food depending on hunger state, with greater levels of hunger increasing attention toward food-related stimuli. Our study utilised this method for two reasons. Firstly, to track changes in attention to food over the time leading up to and following a meal, relative to changes in motivation, with a reliable method. Secondly, to investigate, the phenomenon known as sensory specific satiety (SSS), and its role in implicit processing, by measuring differences in attention to different food types: savoury foods (sandwiches) that had been consumed compared to similar and dissimilar foods that were not consumed. Confirming previous literature on implicit processing, Experiment 1 (Chapter 3) found that attention to food was greater than to neutral stimuli, and that attentional blindness increased in the time leading up to meal consumption. The results demonstrated that attention to food increased with increases in hunger, regardless of food type. In addition, as predicted, after food consumption and the onset of satiety, attention was specifically reduced to images representing foods that were similar to those the participant had consumed (both sandwich-specific and sandwich-general), but not to images of dissimilar foods such as desserts. Importantly, these differences were maintained for up to an hour after consumption. The demonstration that attention to food increases in line with hunger supports comparable research investigating attentional processing of food relative to motivational state (Castellanos et al., 2009; di Pellegrino et al., 2011; Mengarelli, 2012; I. Nijs, 2010; Piech et al., 2010; Tapper et al., 2010), but provides the first report of real-time changes in attention related to spontaneous changes in appetite associated with normal meal patterns – rather than after the imposition of fasting.

In addition explicit ratings of food pleasantness displayed similar declines to attentional processing, following the expectations of sensory-specific satiety (SSS). In particular, SSS devaluations in food pleasantness ratings were observed between the immediate pre- and post-consumption experimental sessions. With the food-type that was consumed (sandwiches) showing larger devaluations than unconsumed food stimuli (dessert). Remarkably the findings of chapter 3 and 4 (experiment 1) demonstrate that attentional bias follows the same direction and specificity of change. Essentially the results from Chapter 3 suggest pleasantness/desirability and attentional capture all decline for food that has been consumed, as predicted by incentive salience. Moreover, the fact that the consumed food is devalued hedonically and its attention capturing power is simultaneously reduced demonstrates a mechanism whereby varying incentive salience can modify motivation-specific behaviour.

The results of this investigation, considered along with research on explicit processes by Cameron et al (Cameron et al., 2014), Weenen et al (Weenen et al., 2005) and Rolls (E. T. Rolls, 2006), and implicit research by di Pellegrino (di Pellegrino et al., 2011), Piech et al (Piech et al., 2010) and Castellanos et al (Castellanos et al., 2009) serve to highlight the underlying neurocognitive processes thought to be responsible for motivational processes, and the similarities between explicit and implicit processes. In particular, they provide further support for the theoretical framework of incentive salience process relative to eating motivation, which suggests that processing motivational stimuli depends on drive/'wanting' and liking. Specifically, the consumption of food has been found to alter neural processing of consumed foods relative to unconsumed food (Berridge & Kringelbach, 2015; Gottfried, O'Doherty, & Dolan, 2003; Kringelbach, O'Doherty, Rolls, & Andrews, 2003). However, an important distinction between Experiment 1 (Chapter 3) and those previous studies is that the present experiment tracked changes over time for both implicit and explicit processing. A key finding of the present study was that changes in attention to food in the pre-prandial stage where not reflected in explicit pleasantness ratings. Suggesting that attentional processing may be more sensitive than explicit processing in gauging 'wanting' food.

The findings of Chapter 3 raised a number of questions. Firstly there were differences in the relative degree of distraction by sandwich images after consumption. These results indicated that images of consumed sandwiches were more affected by changes in appetite caused by their consumption than images of non-consumed sandwiches. Secondly attention to dessert related stimuli appeared to be resistant to changes in appetitive state following food consumption. This ultimately led to us to question of whether this was a reflection of sensory specific satiety (i.e., desserts had not been consumed), or whether sweet or dessert foods in general were resistant to the changes in appetitive state due to their high palatability.

In the second experiment (chapter 4), we attempted to examine this question in more detail, to investigate the degree to which specific types of food vary in their ability to capture attention relative to both motivational state and the consumption of the particular food types. In addition, the experiments of Chapter 4 were also designed to explore the impact of hedonic value on attentional capture by using highly palatable foods. In order to investigate these factors, the stimuli and food consumed were changed and investigated across two experiments. In Chapter 4, participants were provided with one of two sweet foods. In the first experiment (4A) participants were provided with fruit, while in the second experiment (4B) participants were given cheesecake. The findings of both studies showed differing variations in attention to food, relative to changes in motivational state. Essentially attention to fruit, which was rated at approximately the same level of pleasantness as neutral images in an explicit rating task, was influenced by changes in appetitive state as a result of consuming fruit. However, attention to very palatable cheesecake remained high in both experiments. Cheesecake images continued to cause attentional blindness regardless of appetitive state or the type of food consumed.

7.1.2. Hedonic value and salience

Although not entirely unexpected a pivotal and interesting finding of Chapter 4 was that attention to cheesecake did not reflect changes in explicit ratings.

While in Experiment 4A with fruit, as in the original experiment in Chapter 3, pleasantness ratings and attention decreased to the food-type consumed. Specifically all three experiments displayed typical SSS devaluations in pleasantness ratings f for the food-type consumed. Despite the seemingly explicit knowledge of reduced pleasantness and hunger, cheesecake images continued to provoke high levels of attentional blindness on the EBA task.

Other studies have reported that highly palatable foods are more resistant to postprandial changes in appetite. Specifically post-prandial declines in ratings of food pleasantness are known to be reduced for foods with high baseline pleasantness ratings (Stoeckel et al., 2007), and ratings of sweet foods are know to be particularly resistant to changes in appetitive state (J. Johnson & Vickers, 1992b; 1993). In light of the obesity epidemic and predisposing evolutionary factors, its perhaps unsurprising that hedonically potent stimuli remain attractive. In the chaotic and unpredictable environment of the ancestors of *Homo sapiens,* attending to highly valuable foods regardless of state would have been an adaptive benefit for optimal foraging strategies (Lieberman, 2006). This effectively means that the different values assigned to motivational stimuli are differentially influenced by motivation, depending on their hedonic values.

Research conducted by Stoeckel et al on explicit factors (Stoeckel et al., 2007), demonstrated that variations in food pleasantness in a typical taste test were influenced by changes in motivational state. However, a critically important finding of that study was that pre-prandial baseline value given to a food had a crucial influence on post-prandial devaluations in pleasantness ratings. Overall, their findings show that ratings of food are not strongly influenced by changes in appetitive state when the baseline values given to foods were high. Potentially, the baseline hedonic value may also be influencing the degree to which motivational state influences attentional processing of appetitive stimuli. Interestingly, Experiments 4A and 4B provide support for this with, post-prandial pleasantness ratings showing that cheesecake displayed smaller, albeit significant, devaluations in pleasantness after consumption compared to the greater decline in fruit pleasantness. These findings, along with previous research, lead us to question how pleasantness relates to attentional processing.

A recent study by Nummenmaa et al (Nummenmaa et al., 2011) demonstrated that attention to food was partially determined its palatability). In a visual search eye-tracking paradigm, participants were tasked with detecting a target amongst an array of seven images. Participants were quicker to detect appetising foods compared to bland foods or neutral stimuli. Furthermore, neuroimaging studies have also demonstrated that individuals display greater neural arousal for highly palatable foods in areas associated with reward (Frank et al., 2010; Papies, Stroebe, & Aarts, 2008), which are also associated with attentional allocation (Papies et al., 2008).

Considering these previous experimental data, it is perhaps unsurprising that our experiments showed differential variation in the attentional processing of different foods, and that salience of highly-valued palatable/hedonic foods exhibited greater resistance to changes in hunger compared to less palatable foods

7.1.3. A consequence of appetitive state: Intrinsic changes of Affect

A recurring finding across the studies of temporal changes in attentional processing of food (Chapters 3, 4 and 6) was that, inline with changes in appetite, there were reciprocal changes in self-reports of positive affect. Specifically, positive affect declined as appetite increased, while the opposite occurred following satiation. Previous literature refers to hunger as an aversive state, one that individuals would seek to relieve (Canetti, Bachar, & Berry, 2002b). Naturally, relief of hunger provides negative reinforcement to encourage food-seeking behaviour. However, changes in self-reports for the negative scale of the PANAS rarely display increases relative to increases in hunger state. Rather, it appears the individuals become less positive as hunger increases, while food consumption is quite clearly followed by increases in positive affective state. Few studies have reported similar changes in PANAS scores relative to appetitive state. Rejeski et al (Rejeski et al., 2010) demonstrated that the interval between eating episodes has an influence on positive affect in high state cravers, specifically decreasing positive affective state. Similarly, a study of smokers found that abstinence also increased negative affect, and slightly decreased self-reports of positive affective on the PANAS scale (Leventhal, Waters, Moolchan, Heishman, & Pickworth, 2010). Essentially, restriction or length of time between periods of consumption appears to occasion increasing negative affect, although this may depend partially on individual traits (Rejeski et al., 2010). Although few studies have reported similar findings there may be several contributing factors to consider. For example, the majority of investigation utilizing the PANAS scale primarily utilized standard likert scale formats, despite Likert scales being known to be less sensitive than visual analogue methods (Grant et al., 1999; Hasson & Arnetz, 2005). Furthermore, rather than investigating naturalistic changes in affect relative to appetitive state, the majority of studies have instead attempted to manipulate affective state to investigate the influence on appetitive state or the processing of motivational stimuli, such as food (Hermans et al., 2005; see examples Killgore & Yurgelun-Todd, 2006; Mohanty & Sussman, 2013).

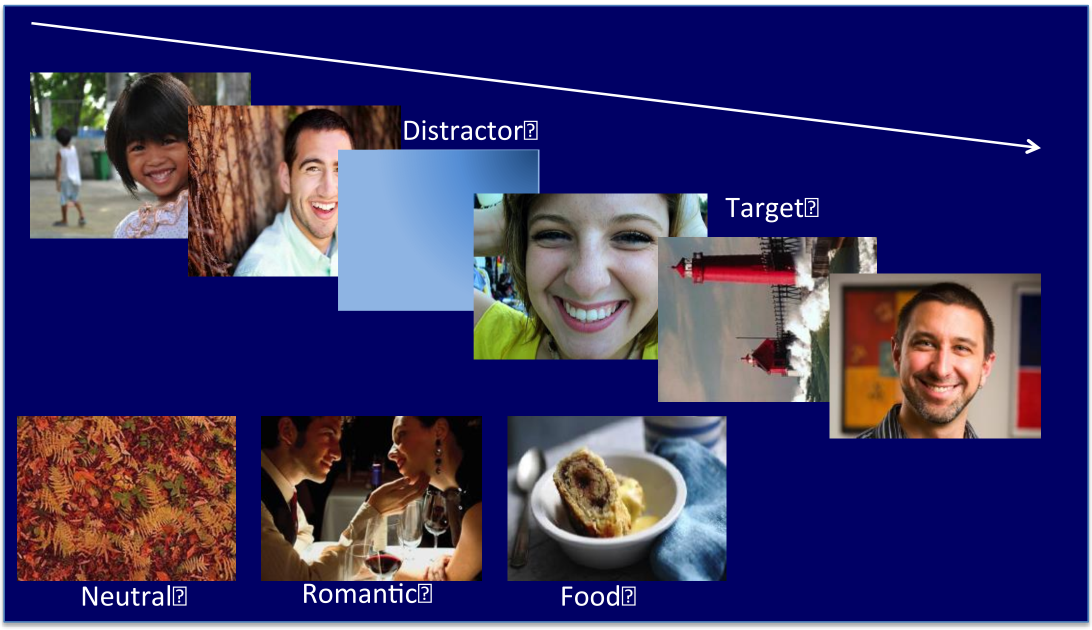
Why is affective state linked to motivational processing? As previously mentioned, detecting environmentally available stimuli and processing stimuli on its moment-based relevance or salience is a fundamental attribute of selective attention (Driver, 2001) which reduces demands on limited executive functioning systems (D. E. Broadbent & Broadbent, 1987; Driver, 2001). Essentially, neural mechanisms reduce the inputs coming from the environment to facilitate the perceptual processing of motivationally and affectively relevant information (Yantis, 2000; 2005). However, information has to compete for processing resources (Desimone & Duncan, 1995; Mohanty & Sussman, 2013) . This competition is regulated by bottom-up (stimulus-driven processes) dependent on stimulus salience, or top-down processes regulated by endogenous information. As a consequence, studies have shown that changes in appetite may influence changes in neural responses to the presentation of food-related stimuli (Mohanty et al., 2008), particularly of neural activity in areas associated with affective processing.

Critically, it is likely that changes in areas associated with affective processing influence the salience of environmentally available stimuli, making detection of motivationally relevant stimuli easier. A variety of studies demonstrate that attentional processes are drawn to emotional arousing stimuli (see Vuilleumier, 2005). These effects have been found with a variety of implicit experimental tasks: dot-probe tasks (Armony & Dolan, 2002; Tamir & Robinson, 2007), inhibition of return (Rutherford, O'Brien, & Raymond, 2010) and spatial visual search (Eastwood, Smilek, & Merikle, 2001; Fox et al., 2001; Ohman et al., 2001). In dot-probe tasks, individuals are commonly slower at identifying a probe appearing after a word or picture when the stimulus has emotional relevance, despite emotion being irrelevant to the task. Visual-search tasks tend to show that detection of a target amongst irrelevant distractors is faster when it is emotionally arousing (Eastwood et al., 2001; Fox et al., 2001; Ohman et al., 2001). Relevant to the findings of Chapters 3 and 4 is the demonstration by Kilgore et al (Killgore & Yurgelun-Todd, 2006) that differences in positive or negative affective state accounted for variations in the neural processing of food-related stimuli. In conclusion, suggests that both endogenous and exogenous affective information influence our implicit processing of surrounding environments (see review Mohanty & Sussman, 2013)

7.1.4. A consequence of affect: Exogenous Motivational Processing

Chapter 5 investigated the influence of affective processing further. Rather than manipulating motivational state via tracking changes over time between meals, Experiments 5 utilized affective priming through the presentation of emotional faces within EBA streams. Previous studies, such as chapters 3 and 4 along with other studies (Leventhal et al., 2010; Rejeski et al., 2010; Seibt et al., 2006) found that changes in hunger alter explicit self-reports of affective state. However this is distinct from research using mood-induction procedures to investigate the influence of affective information on processing motivational (hunger) objects, such as food (Hermans et al., 2005; see examples Killgore & Yurgelun-Todd, 2006; Mohanty & Sussman, 2013). As previously stated these studies have found that affective inducement procedures enhance processing of motivational stimuli. Experiment 5 attempted to build on this notion that motivational and affective processing interact, using affective priming (see Figure 7.1.1).

A



B

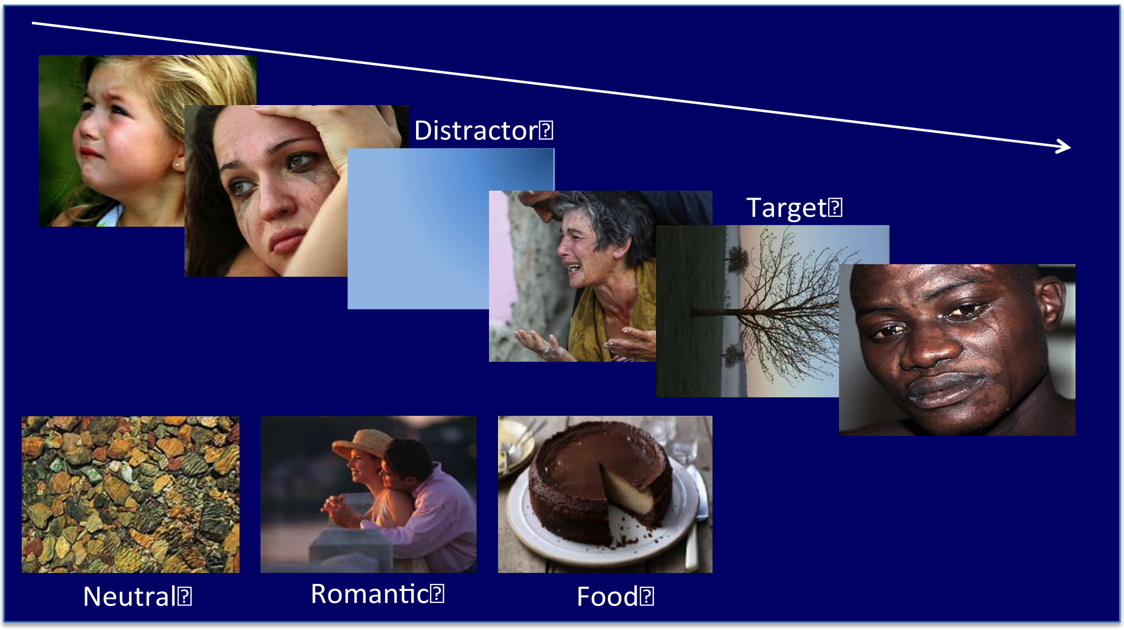


Figure 7.1.1 Affective priming RSVPs used in Chapter 5. Positive priming (A), negative priming (B).

Specially experiment 5 found that positive affective priming exerted a strong influence on the salience of motivational stimuli, increasing attentional blindness for food stimuli. By contrast, negative priming was found to exert no influence on the attentional processing of food. Both findings were somewhat unexpected. Generally, the neurocognitive literature has found affective (+ve/-ve) priming to influence changes in motivational processing of food influencing the valence of appetitve stimuli (Reynolds & Berridge, 2002; 2003; 2008). Specifically Reynolds and Berridge (1998) have found that exposure to negative environments decreases the valence of appetitive stimuli, while positive affective environments enhance valence. These changes in valence are thought to influence attentional processing (Pessoa, 2008; 2009; Pessoa & Adolphs, 2010) of these appetitive stimuli with positive affect increase attention to food while negative affect should decrease attentional processing of food (Berridge & Kringelbach, 2008; 2015; Frijda & Sundararajan, 2007). However, cognitive literature has been inconsistent, with commonly finding inducement of negative affective state occasionally increasing the attentional selection of rewarding stimuli (Bekker et al., 2004; Bongers et al., 2015; Dingemans et al., 2009; Evers et al., 2010; Hepworth et al., 2010; Wallis & Hetherington, 2009; Willner et al., 1998). Only occasionally negative priming has not been found to enhance attentional processing of food (Bongers et al., 2013) or food consumption (Evers et al., 2010; Wallis & Hetherington, 2009). While positive inducement has very rarely been reported to enhance attentional processing of food in cognitive studies (Bongers et al., 2013; Winkielman & C Berridge, 2004).

Importantly a key finding of the thesis regarding affective processing is that there is a clear difference between the influence of endogenously generated changes in affect and of exogenous information inducing changes in affective processing. The findings of Chapters 3 and 4 show that affective state changes relative to motivational state/appetite. Using our affective EBA method, affective information within an RSVP does not necessarily change affective state, but does influence the salience of motivational stimuli. These findings seem to reflect discoveries in cognitive neuroscience suggesting that affective processing influences the hedonic values and salience of motivational objects, and in particular food, as suggested by Berridge and Reynolds (Berridge & Kringelbach, 2015; Reynolds & Berridge, 2002). Essentially, our paradigm is one of few methods that has been able to consistently demonstrate that positive affective priming may influence implicit processing of food.

7.1.5. Motivational fluctuations and affective priming

The results of Chapters 3 and 4, along with recent cognitive neuroscience studies (Reynolds & Berridge, 2008) have found that motivational and affective information, both endogenous and exogenous, interact to influence the salience of motivational objects. Thus, satiation on a specific food was associated with reduced attention to images of that food. Separately, we found that positive affective images increased attention to food images. We therefore speculated whether satiation-related and affect-related influences on attention to food would interact, such that the post-meal decline in attention to consumed food might be reversed by presenting positive affective imagery within the postprandial EBA streams.

Although the results of this final study were not exactly as predicted (due partly to confounds arising from the specific design), we were able to show that positive affective priming was influential in increasing the attention to food when individuals were sated. Unfortunately, in this instance the expected SSS-related decline in attention to images of lunch sandwiches was not replicated, despite a SSS-consistent differential decline in the palatability of the eaten food compared to non-consumed foods. Nevertheless, the ability of postprandial affective priming to enhance attention to food would be consistent with a general effect to enhance its salience in a way that is independent of explicit measures of motivation to eat and food palatability.

These finding are possibly a consequence of bottom-up affective information modulating implicit processing of hedonic-values, or alternatively providing information about the environmental context in which motivational cues appear (Reynolds & Berridge, 2002; 2008). Other research has previously suggested that affective information acts to reduce complex information about the environments we live in and act as a rough measure for analyzing the complex and vast information received from our environments (Dreisbach & Goschke, 2004; Isen, 2001; Isen & Reeve, 2006; Mohanty & Sussman, 2013; N. K. Smith et al., 2006). Positive affective information thus appears to facilitate, or indeed prioritize, the ability of intrinsically rewarding stimuli to gain access to attentional processing. Further experiments are required to clarify these issues using improved designs, and to specifically explore whether the ability of positive imagery to enhance attention to food would be translated into changes in motivation to eat and actual consumption.

7.2. Theoretical Implications

The theoretical implications of this research involve a combination of support for incentive salience and sensory specific satiety, and some enhancements of current understanding of these principles in cognitive research. Overall, it would seem that attention is drawn to food to a greater extent than more mundane stimuli, as predicted by the incentive salience framework. In addition, as predicted by both incentive salience and sensory specific satiety, attention to food respectively increases and decreases with rising and falling motivation to eat. Importantly, when a desirable food is eaten to satiety, that food loses its capacity to capture attention relative to other, non-consumed foods – even foods which share similar categorical features. Additionally, reduced attention to a food that was eaten is also associated with the post-consumption decline in the pleasantness of that food. We have clearly demonstrated a close link between attention and eating motivation (and arguably the separate components of wanting and liking), and shown that these variables are closely correlated in non-deprived individuals exhibiting natural, spontaneous changes in appetite. However, attention to certain, highly palatable foods appears to be independent of this relationship and, in particular, they are resistant to the post-consumption decline in attention capture seen with other foods. While this resistance (indicative of the power of these highly palatable foods to encourage further eating even when an individual is otherwise sated) is not uncommon in explicit research, it had not previously been documented in studies of implicit processing. Overall, attention can be seen to be an important component of the processes whereby appetite that arises from either endogenous or exogenous factors is translated into behaviour. Naturally occurring hunger promotes attention to food cues. When we are sated attention to food is attenuated, allowing cognitive resources to be directed toward other features of our environment. In the absence of need, high-hedonic foods can however still capture attention – which, in turn, may re-ignite the desire to eat and promote further eating. Attention to food, thereby, is directly related to its incentive value; attention capture by food stimuli thus provides a direct measure of incentive salience.

In addition, the findings of appetite-related changes in affect present some interesting questions about the interactions between affective and motivational processes. Specifically, increases in appetite are accompanied by reduced positive affect and increasing negative affect: opposite changes are found following satiation. Consuming food is a pleasant and reinforcing experience, so this is not unexpected. However, few studies have tracked changes in affective processing over time relative to appetitive state. Crucially, it is important to consider whether these changes in the affective system might be related to changes in attention. Recent research seems to imply that affective information influences the scope of attention and, more importantly, may compel individuals to seek out the remedy for negative affect arising from a motivational deficit (in this instance, food is required to alleviate hunger). Essentially, hunger is negatively reinforcing of food seeking behaviour, while food consumption is positively reinforcing. This concept is not entirely novel and finds some support from cognitive neuroscience, with studies finding that changes in the amygdala (strongly associated with attributing affect valence) predict the reward value of stimuli (Gottfried et al., 2003). In addition, these affective areas play a crucial role in the neuroarchitecture of the reward system which controls hedonic value (Berridge & Kringelbach, 2008; 2015; Reynolds & Berridge, 2002; 2008) and mediates attention (Pessoa, 2008; 2009; Pessoa & Adolphs, 2010). Taken in the light of cognitive neuroscience, the present findings are relatively complementary to existing models.

Affective information being received from the environment (bottom-up/exogenous) at an implicit level provides a separate, although related function. Bottom-up affective information primarily acts to provide contextual colouring (N. K. Smith et al., 2006), by reducing the complex information about the environment into affective information (De Houwer et al., 2009; Isen & Reeve, 2006; Mengarelli, 2012) that may be used to influence hedonic value of motivational stimuli such as food. Much recent research seems to suggest that negative affect (following mood induction) increases attention to food (Bekker et al., 2004; see Hepworth et al., 2010;

Willner et al., 1998), although this is not what we have found. Attention is drawn towards a positive motivational stimulus that may relieve a negative state or, rather, return the individual to a more positive state, as seen in the changes of positive PANAS scores throughout the thesis. Similarly, research with clinical populations has found that stress causes increased attention to food-related stimuli, with anxious people (Mogg et al., 1998). Interestingly no study has yet provided participants with a threatening situation, although this may be a difficult experience to investigate.

A critical factor of affect in the studies included in this thesis is the distinction between changes in affective state as a result of deprivation and changes as a result of priming. Specifically deprivation of food in studies resulted, occasionally, in changes of explicit reports of affective state. While positive priming using multiple primes enhanced attention towards food, despite no changes in hunger. These are two very different types of information, with internal signals (hunger) changing affect. While external signals changing affect, may influence implicit motivational processing.

While positive affective images did not in themselves exert any influence on neutral stimuli, they enhanced attention towards food. However positive stimuli did not increase positive affect. Changes in the areas of the brain associated with affective processing are known to regulate attention (Pessoa, 2008), while changes in the 'reward systems' impact areas of the brain associated with affect and attention (Berridge & Kringelbach, 2008; 2015). Referring back to Reynolds and Berridge (Reynolds & Berridge, 2002; 2008) affective information received from the environment regulates activity in brain regions associated with hedonic values, in particular the NA. It would seem from our experiments that both affective and motivational information is influencing object salience, while interacting with each other. Specifically these changes in salience mediate attentional processing (Pessoa, 2008; Reynolds & Berridge, 2008). However this does not account for the inability of negative priming to reduce attention towards food, it would seem that negative affective information does not enhance attentional processing of food when observed implicitly.

Furthermore, positive affective information received implicitly seems increase attention to motivational stimuli, complementing cognitive neuroscience. The effects seen in Chapter five regarding positive priming, demonstrated that affective information acts as a critical factor that contextualizes the motivational processing. Namely that positive affect encourages individuals to take advantage of their environments, if motivational objects are present. Following research from incentive salience (Berridge & Kringelbach, 2015; Reynolds & Berridge, 2002; 2008), it is thought that positive affect positive enhances the hedonic value of motivational stimuli. While motivational stimuli themselves seem to hold baseline values that may be influenced by motivational state, when the baseline hedonic value is intrinsically weak. Furthermore changes in motivational state seem to impact on affective state, the impact of which is yet to be fully explored. However the full implications of these studies require far more depth of investigation, and perhaps should be considered in light of their limitations, and other experimental issues.

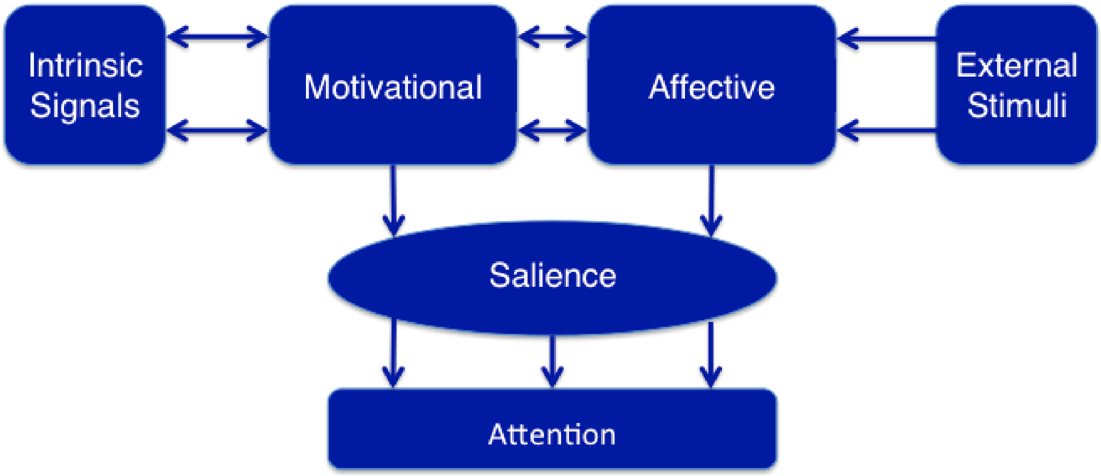


Figure 7.2. Diagram of the interaction of motivational and affective processes

7.3. Limitations and methodological considerations

Previous studies have shown that different weight groups respond differently to food related stimuli (Nummenmaa et al., 2011) this would be interesting to in investigate over time. While other individual differences such as restrained, external and emotional eating have long been known to influence food consumption (Cebolla, Barrada, van Strien, Oliver, & Baños, 2014; van Strien et al., 1986; Van Strien & Van de Laar, 2008). The present thesis did not collect statistically enough numbers in in any of these categories to analyse these differences. These individual differences are something future studies should consider.

Although measures of different traits relative to eating were measured: external, emotion, and restraint, the numbers of participants classified by these measures was not enough to statistically justify separate analysis. Furthermore reward sensitivity, which is often, mislabelled hedonic hunger, was also not taken into account in this study despite its potential interest. Additionally a critical study investigating implicit processing has shown that working memory capacity plays a significant role in how individuals respond to cues in their environment (see Thrush, Wiers, Ames, Grenard, Sussman and Stacy, 2007).

7.4. Application of findings

The EBA method appears have potential utility in investigating differences in the salience and consequently the hedonic-value of different food types. However the sensitivity of the EBA task has not been fully investigated, nor has it been investigated with a large range of foods. In addition the findings suggest that future studies should take consideration of how affective information and affective states influence motivational processing. Further understanding of affective processes and its influence on motivational processing may enhance investigations of appetitive behaviour.

7.5. Concluding remarks

In summary the experiments of this thesis examined the relationships between motivational and affective processes with implicit and explicit cognitive measures. The primary finding of the thesis is that attention, or rather the salience of food, is often influenced by an individual's motivational state. However, implicit processing of food is likely to be influenced by baseline hedonic-values of food, with more palatable foods which possess intrinsically high incentive value being maximally distracting irrespective of appetite level, and consequently attention capture by them being resistant to changes in appetitive state. Secondly attentional processing of certain appetitive stimuli such as sandwiches and fruit, appear be influenced by appetitive state specifically the large changes in appetitive state as a consequence of consumption. Furthermore, the thesis demonstrated that explicit experience of affective state is influenced by changes in motivation. Specifically this may indicate that deficit/high motivation is experienced negatively, while satiation is rewarding, this may compel and individual to seek out the remedy for negative affect associated with high levels of motivation. Bottom-up affective cues, or primes, serve to inform individuals about their environment implicitly, influencing the salience of motivational objects, particularly food, enhancing their capacity to capture attention and guide goal-seeking behaviour. In conclusion, these results suggest that there are distinct differences in how endogenous and exogenous information influence motivational and affective processing. The findings affirm that motivational and affective cognition are strongly related but separate processes that influence our interactions with the environment.

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