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Investigation of food 'wanting' and 'liking' in free-living individuals using a novel smart phone application: mind eating

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INVESTIGATION OF FOOD 'WANTING' AND 'LIKING' IN FREE-LIVING INDIVIDUALS USING A NOVEL SMART PHONE APPLICATION: MIND EATING

By

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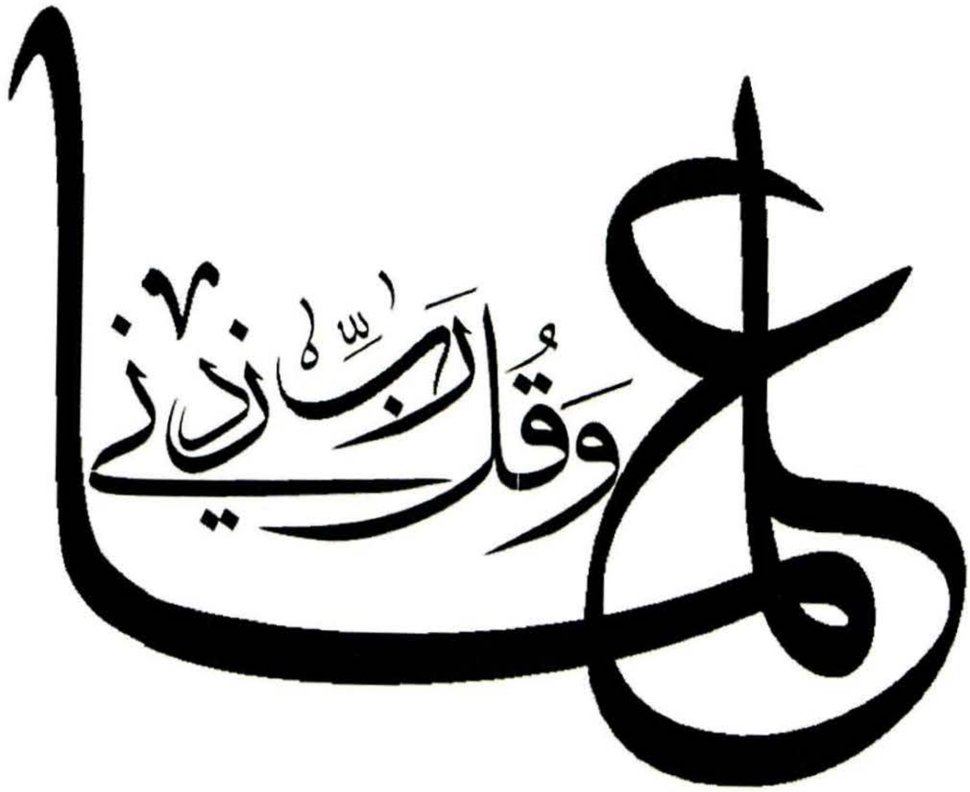
A Thesis submitted to the School of Sport, Health & Exercise Sciences, Bangor University in fulfilment of the requirements of the degree of Doctor of Philosophy

Jan 31st, 2016

Supervisor: Dr. Hans-Peter Kubis



"My Lord Increase Me in Knowledge" Quran 20:14

Dedication

I dedicate my PhD to Kuwait University, for altering the path I chose in their computer science department over which I spent 5 years of my academic life and ended up out of track, with all my efforts un-counted. Their reluctance and lack of fairness put me on a fresh trajectory that resulted in my current opportunity. They are welcome to keep their abominable job; letting student go is the best way to release their potential, apparently!

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Summary

A lifestyle of reduced physical activity and eating energy dense foods has resulted in a worldwide obesity epidemic. It is assumed that overeating is driven by hedonic rewards rather than by homeostatic factors of energy intake. Hedonic rewards are consummatory, 'liking' (e.g., satisfaction and palatability), or anticipatory, that is, 'wanting' (craving). Continuous patterns of wanting and liking of food as a potential explicit expression of reward anticipation and incentive salience, as well as consummatory reward perception have not yet been investigated in real-life situations over longer time periods; therefore, the time dimensions of perception and action in eating behaviour are not fully understood. These patterns in perceptions and their intensities (wanting and liking of food) might be important for understanding mechanisms in obesity and its treatment.

In this thesis we are aiming to targeting those gaps in knowledge by a field-studies which might therefore add valuable information and confirmation to tradition lab-based and questionnaires studies that have limited design and techniques. Consequently, a new method in measuring the "wanting" and "liking" is aimed to be developed to measure these hedonic rewards components in real-life scenario. Finally, we are aiming to investigate the influence of exercise on these components in sedentary, lean and overweight individuals.

Therefore, firstly in Study1 we have developed and piloting the "Mind Eating" smart phone application to record and score 'wanting' and 'liking' events under real life conditions. This application could function on both operating systems IOS/Androids and available for the research in Apple and google store. This application designed to be simple and easily used with a connected online database to revealed the data at any time by

the researchers. A pilot study design in chapter 2 was aimed to examine the functionality and performance of the developed phone application according to the design specifications. Twenty two participants (lean n=17, overweight/obese n=5) were recruited from Bangor university staff and students. The smart phone application (Mind Eating) was used to track of participants 'wanting' and 'liking' of food and drink. The pilot study resulted into enhance some text interface of the application, reducing the period time of the experiment from 4 to 2 weeks and fix some capability of the the application to perform without network existence.

Then in Study 2, "Mind Eating" application was utilised to gain a deeper insight into the psychological drivers of overweight and obese individuals. We aimed to analyse continuous patterns of 'wanting' and 'liking' of food in real life situations. We compared high body fat percentage (H-Fat) individuals with low body fat percentage (L-Fat). The following variables were measured: 'wanting' leading to eating events (WE), 'wanting' that did not lead to eating ('wanting' but resisting events, WR) and 'liking' after eating events (L). First part of the results which was an aggregate data analysis, revealed that the L-Fat group recorded significantly more food 'wanting' and eating events than did the H-Fat group. Both groups showed similar patterns for WE, WR, and L, but these scores differed significantly only within the L-Fat group. A strong trend ($p = .052$) towards higher L scores was found only in the L-Fat group but the two groups did not differ significantly in WE or WR. A Second part of the result was the (Time series analysis), this study was the first to analyse time series data on eating behaviour. Both groups showed a similar periodicity in unsuccessful and successful 'wanting' throughout the day. The 'liking' vector for the L-Fat group remained constant for the rest of the day following the morning meal. In contrast, the vector of 'liking' for the H-Fat group disappeared over the same time period. The disappearance of periodicity in 'liking'—but not in 'wanting'—in H-Fat individuals means that 'wanting' and 'liking' are not linked or coupled in this population. This suggests that reward processing in the brains of overweight/obese individuals is not same as in lean people and may be dysfunctional.

Finally, in Study 3, we investigated the effect of a single bout of exercise on the 'wanting' and 'liking' of food and drink in lean and overweight sedentary individuals. Participant (N=18, lean n=8, overweight n=10) randomized in in a repeated measures crossover type design study with an exercise and control trial and full randomized order of trials. Food Craving Questionnaires-Trait (FCQ-T) was administered as a baseline test and the Food Craving Questionnaires- State (FCQ-S) was measured during both experimental trials at three time points; immediately before (Pre), immediately post (Post) and 1 hr post (1Hr) exercise. The "Mind Eating" application was used to measure participants 'wanting' and 'liking' of food and drink, 24 hours before and 24 hours after both trials. Exercise changed the scores for the physiological and psychological dimensions of eating behaviour in both groups. In the overweight group, exercise reduced the perception of 'wanting' and meal frequency, and suppressed the intense desire eat.

To conclude, "Mind Eating" Phone application could offer for future a new approach in measuring the patterns in perceptions and their intensities (wanting and liking of food). Our data collected in free-living condition with a novel smart phone application could be interpreted as a strong support for reward deficiency in overweight/obese people while several observations point towards a more complex problem with involvement of enhanced craving contribution for wanting without integrating former consummatory reward information into the reward expectation. Finally, overweight individuals are shown to be more influenced by hedonic drivers of eating behaviour than are lean individuals. This could explain differences in anthropometric characteristics and the response to exercise for two groups.

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Contributions

- **Chapter 3:** All data was collected by myself and in collaboration with Marion Cliffe from Department of Nutrition and Dietetics, Betsi Cadwaladr University Health Board, Ysbyty Gwynedd, Bangor, Gwynedd LL57 2PW, U.K. Email: marion.cliffe@wales.nhs.uk

- **Chapter 4:** All data was collected in collaboration with Rohan George Mathew in his Master degree study

Publications (Under review) in *Appetite Journal*

Chapter 3:

- **Obese adults gain less reward from eating during daily life, using a novel smartphone application: Mind Eating**

  Kholoud Alabduljader, Marion Cliffe[b], Hans–Peter Kubis

Published abstracts

- Matthew Jackson, Kholoud Alabduljader, Kirstie Tew and Hans-Peter Kubis (2012). Effects of a 4-week exercise intervention on body composition, energy balance and metabolism in lean and overweight/obese women. *Proceedings of the Physiological Society* 27, PC113.

- Kholoud Alabdujader[1], Marion Cliffe[2], Hans-Peter Kubis[1] (2015). Food 'Wanting' and 'Liking' in free-living lean and obese participants using a novel smartphone application: Mindeating. In *22nd European Congress on Obesity (ECO2015).*

CHAPTER 1

1. LITERATURE REVIEW

1.1 Introduction

The worldwide prevalence of obesity is considered a growing phenomenon. In 2008, the World Health Organization (WHO) reported that 35% of the global adult population is classified as overweight (BMI >25kg/m^2) and 11% as obese (BMI > 30 kg/m^2). Obesity figures trebled since 1980 and in England, one in four adults is classified as obese (Craig, Mindell, & Hirani, 2009). The obesity epidemic is also a key contributor to the rising incidence of diabetes, hypertension, hyperlipidemia, cardiovascular disease and some forms of cancer (JC, 1995; Prentice & Jebb, 1995). In addition to obesity, disorders such as anorexia, bulimia and related appetite and eating disorders have become more prominent, too. National health services are becoming increasingly saturated with the health consequences of unhealthy weight, and obesity has become a major concern for most Western governments. The academic and practical focus is now rapidly moving from treating the consequences of obesity towards prevention (James, 2008). Nonetheless, behavioural and pharmacological treatments of obesity itself are also needed. While some external factors which can contribute to weight gain and obesity, such as modern diet rich in energy dense foods, excessive food cues and urban lifestyle, cannot be ignored, it is also important to understand these environmental and societal influences in the context of the individual's characteristics, preferences and unique biopsychology (Berthoud, 2011; Harrold, Dovey, Blundell, & Halford, 2012). Especially knowledge on homeostatic regulatory mechanisms could contribute to our understanding of eating choices and behaviours observed among the general population and juxtapose it against the environment hedonic aspects (Harrold et al., 2012; Rios, 2011). How and why some individuals become obese is a subject of a major debate in obesity research. Some individuals appear to be more able to keep their bodyweight stable throughout their lives compared to their peers who live in a comparable environment (Berthoud, 2011). Initially, it has been proposed that obesity results from an imbalance of energy intake and expenditure; a reduction in the levels of physical activity is combined with the inability to down regulate energy intake to match the decreased energy expenditure (Moore, 2000).

This view might, however, be too simplistic and appetite regulation as well as obesity are now recognized as a result of a complex interaction between many influences and factors (Harrold et al., 2012). More than a hundred factors with a direct or indirect impact on energy balance have been described in a report by Butland et al. (2007), including biological, genetic, social, environmental and psychological factors, as well as individual's eating behaviours and activity patterns (Butland et al., 2007).

Some authors explored the possibility of genetic factors underlying some cases of obesity, in particular in relation to factors contributing to unexplained heritability of obesity (De, Ting, Moore, & Gilbert-Diamond, 2015; Kogelman et al., 2015; Ngwa et al., 2015). Twelve genes have so far been robustly associated with obesity and research on obesity did not yet find a single gene defect (De et al., 2015). However, knowledge on genetic factors can be helpful as demonstrated by Farooqi et al. (2002) who studied morbidly obese children congenitally deficient in leptin and treated them with human leptin injections to normalize their appetite, fat mass, and insulin and lipid levels. Nonetheless, it has been proposed that obesity is more likely a result of an interaction between many susceptibility genes and an obesogenic environment (Berthoud, 2004). The latter has become almost impossible to avoid and numerous food-related signals are a part of the omnipresent and powerful marketing strategies. The media constantly portray mouth-watering advertisements. Restaurant portions have grown to unprecedented sizes, and snacking on calorie-dense foods is normal (Rolls, 2003). Furthermore, different psychological techniques can be used in food advertisements to link particular food with a promising and encouraging self-image or to create a perception of food that would support purchase (Geyskens, Pandelaere, Dewitte, & Warlop, 2007; Letona, Chacon, Roberto, & Barnoya, 2014) . Social aspects exert a strong effect on individual's eating habits, with socioeconomic status, peer pressure and culture all being relevant (Berthoud, 2004).

As previously mentioned, in any particular group of individuals that exists within the same culture, we can find some who gain weight and some who do not (Berthoud, 2011; Blundell & Finlayson, 2004). Furthermore, it is interesting to note that the number of those who cannot maintain a healthy weight is sharply rising. In the UK, it also appears that obesity is now more prevalent in the most deprived areas compared to the least deprived (Relton et al., 2014). In extreme, addiction-like behaviours towards food have been observed worldwide (Berthoud, 2011). It has been argued that the susceptibility of some individuals to gain weight is a result of food overconsumption. A person's eating pattern involves the size and frequency of eating episodes and food choices, which together determine the total energy and macronutrient intake (Blundell, 1991; Blundell & Halford, 1994; Martins et al., 2008).).

Since many people are exposed to comparable environmental factors that can act as appetite triggers, the variation in overconsumption could be to some degree related to the variations in their intrinsic psychobiological mechanism (Blundell & Finlayson, 2004). In line with this, reward mechanisms are recognized to be at the centre of the current appetite research, especially the distinction between the homeostatic and hedonic (reward) mechanisms and how they relate to overconsumption and energy balance problem (Berthoud, 2011; Harrold et al., 2012; Rios, 2011). How much we eat, when and what we eat - all these factors appear to be influenced by brain reward mechanisms.

1.2 Brain Reward System of Food Hedonics

Over the last 15 years, neuroscience research has yielded several unexpected findings on the neural basis of food sensory pleasure. Three components of reward have been described: (1) liking - the pleasure component or the hedonic impact of a reward, (2) wanting – motivation for reward, which consists of incentive salience processes and conscious desires, and (3) learning – the use of past experience to predict a reward and build associations (Berridge & Kringelbach, 2008). Berridge's work (1996-2014) linked motivational 'wanting' and 'liking' with mesolimbic dopamine system and proposed a causal relationship between dopamine and reward. In the early 2000s, this development has been aided by the discovery of anatomically localized brain subregions called "hedonic hot spots", in which the hedonic impact of sensory pleasure is amplified by opioid activity (Peciña, Smith, & Berridge, 2006; Smith & Berridge, 2005; Smith & Berridge, 2007; Thompson & Swanson, 2010). Evidence suggests that these hot spots are located in the limbic-related brain structures, and have the ability to increase the hedonic effect of natural sensory reward, e.g. sweet taste (Peciña & Berridge, 2005; Peciña, Smith, & Berridge, 2006). Specifically, they have been found in the forebrain nucleus accumbens, particularly in the medial shell, ventral palladium and in the brainstem parabrachial nucleus (see Figure 1.1). The hot spots are able to causally amplify positive affective reactions to palatable tastes ("liking") as a reaction to neurobiological or neurochemical stimulations (Peciña & Berridge, 2005; Peciña, Smith, & Berridge, 2006). Animal research has revealed that administering microinjections of DAMGO, an μ-opioid agonist, increases the 'liking' of sucrose. This heightened affinity applies to both neural (ventral pallidum neuron firing signals) and behavioural (a higher number of affective taste reactions that are positive) responses (Smith, Berridge, & Aldridge, 2011). These mechanisms are partially distinct from the larger mesocorticolimbic circuitry which produces the incentive motivation to eat ('wanting') (Castro & Berridge, 2014). The "wanting" component occurs via dopamine release in mesocorticolimbic pathway before or during one is exposed to food. It is important to consider that the motivation to consume certain foods stems from dopamine action rather than opioids. Research also makes clear that opioids alone, without dopamine, are nevertheless able to prompt affective responses (Smith et al., 2011).

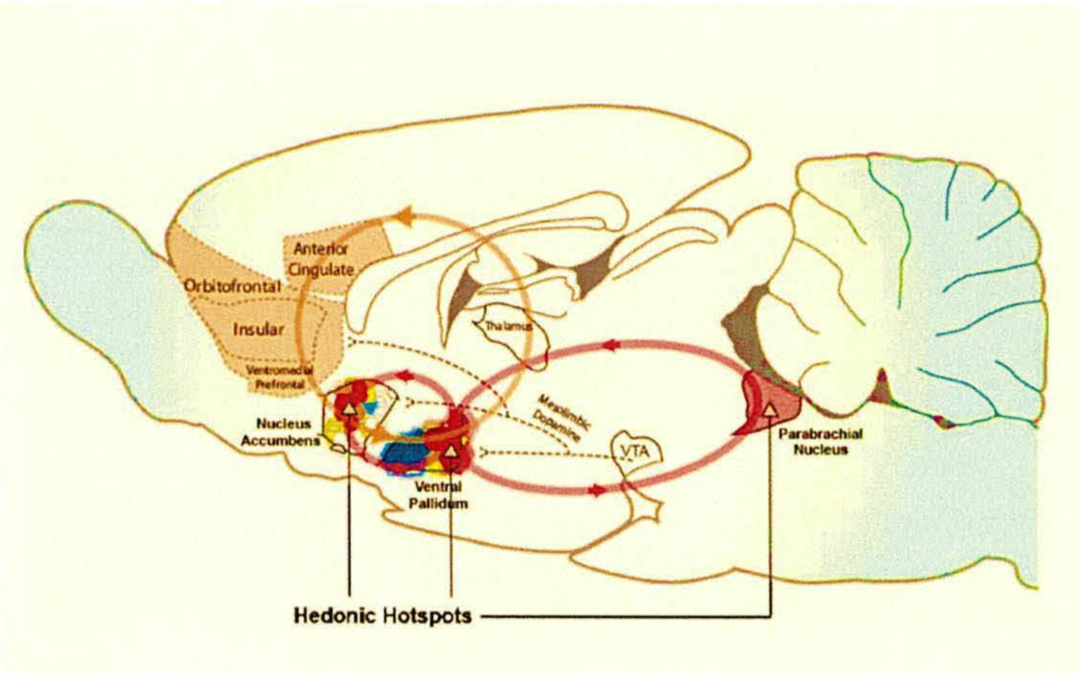

Figure 1.1. Hedonic hotspots and hedonic circuits.

Hedonic hotspots have been identified in nucleus accumbens, ventral pallidum and brainstem parabrachial nucleus where opioid or other signals cause amplification of core 'liking' reactions to sweetness. Modefied from Smith et al. (2008), based on Kringelbach (2005), Peciña et al. (2006), and Smith and Berridge (2007).

There is a motivational effect carried by the palatability of food. For example, seeing a piece of cake or even just the smell of a favourite dish might induce a sudden urge to eat. At the same time, the taste of this food could also encourage one to eat more. In the modern, food-rich world, these cue-triggered can gradually lead to the obesity and overconsumption problem in some people (Berthoud & Morrison, 2007; Davis & Carter, 2009; Holand & Petrovich, 2005; Kessler, 2010) (see Figure 1.2).

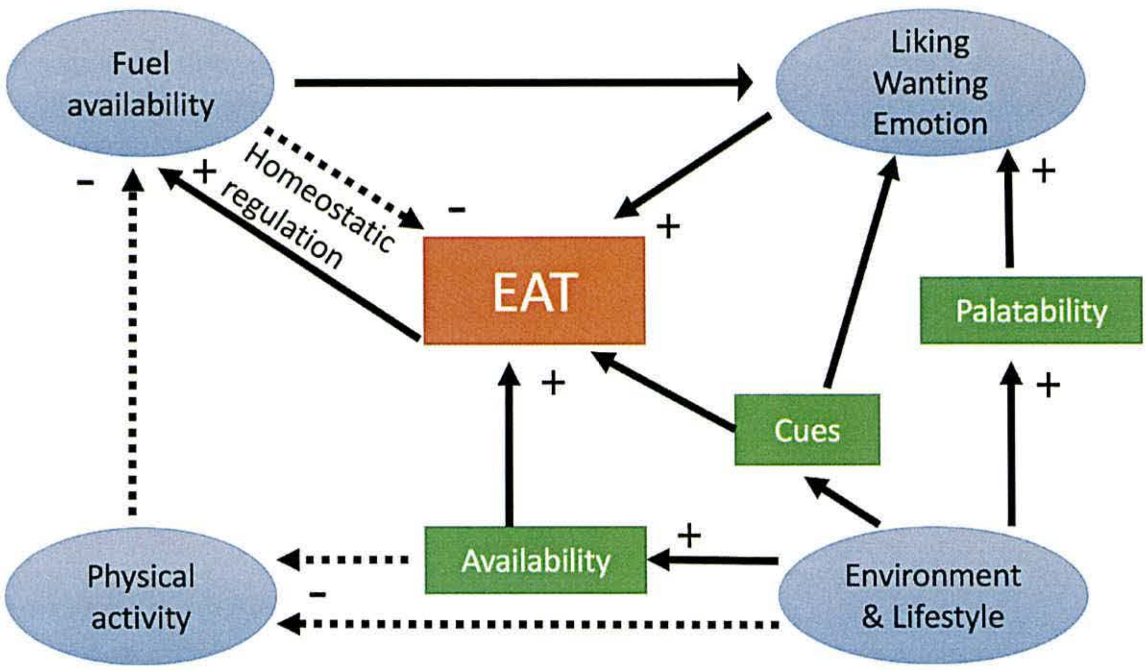

Figure 1.2. Interaction between homeostatic and hedonic (Metabolic and cognitive) system of control of food intake and energy balance.

Modified from (Berthoud & Morrison, 2007).

However, food or cues are not the only triggers for this motivational power. Some individuals appear to have a greater, or even irresistible urge, to overeat compared to their peers. The neurobehavioral mechanisms responsible for overeating have not been fully understood yet, however, stress and anxiety appear to play a role in binge eating and eating disorders (Bardone-Cone, Brownstone, Higgins, Harney, & Fitzsimmons-Craft, 2012; Izydorczyk, 2012; Liu, 2015). When experiencing negative affect, some individuals can find it difficult to control the urge to overeat or drink as found in the sample of women subjected to high levels of academic stress and the pressure for perfectionism (Bardone-Cone et al., 2012). The motivational power appears to vary from individual to individual, and from one occasion to another. It might be that it gets momentarily, dynamically generated by mesocorticolimbic brain systems that get influenced by dopamine and opioid neurotransmitters in nucleus accumbens as proposed by Peciña and Berridge (2013)..

Berridge's research work (1996, 2014) also focused on the pleasure and temptation for sweet, salty and fatty foods. These sensations appear in the brain, not just passively, but as active neural systems generating the reaction of "wanting" and "liking", which together enhance the pleasure of the sensation and add to the smell, taste and sight of food. A tempting chocolate cake might not always be delicious, however, our brain have been influenced to actively initiate "liking" of its chocolaty creaminess and sweetness. These sensations might be the key to unlocking the brain circuits which produce pleasure and desire at the moment of encounter with food (Berridge & Kringelbach, 2008; Berridge, Ho, Richard, & DiFeliceantonio, 2010).

Since the hedonic bias is not always stable, the active brain generation is considered to be flexible. For example, an intense salty taste could be reversed and become pleasant when the body lacks sodium, producing a salt-craving moment. On the other hand, the ability to taste bitterness has developed in most animals as a safeguarding mechanism to protect against potentially toxic substances and food compounds. Bitter taste, the most complex of human tastes, has therefore been evolutionary designed to be perceived as unpleasant, leading to food rejection (Beckett et al., 2014; Roudnitzky, 2015). However, hedonic flexibility can make the bitter taste of coffee, beer or cranberries pleasant for some people, especially once the culturally-induced experience has transformed this bitterness into a key for hedonic systems (Berridge et al., 2010). Moreover, it appears that people differ in their ability to detect bitter compounds and there are many polymorphisms in the whole-family of TAS2R genes that influence individual's sensitivity to bitterness (Beckett et al. 2014). Generally, however, food becomes highly "liked" in states of hunger, while "liking" will be reduced in states of satiety at different times in the same day (Cabanac, 1971).

1.3 Hedonic vs Homeostatic Reward System

The reward circuitry of the brain governs hedonic appetite, with its function being largely mediated through the transmission of opioids and dopamine within the striatum. In contrast, it is the hypothalamus that governs homeostatic appetite, acting in response to the body's energy needs as communicated to it by internally generated signals. It controls the need to eat using sensations of feeling hungry or sated (Lutter & Nestler, 2009). The homeostatic and hedonic systems share a considerable overlap in their effect on food consumption (Berthoud, Zheng, Corkern, & Stoyanova, 2010; Finlayson, King, & Blundell, 2007; Saper, Chou, & Elmquist, 2002) (see Figure 1.4). The two systems function together to preserve appropriate energy levels by monitoring energy needs in both the short-term, termed "episodic" requirements, and the longer-term, or "tonic" requirements (Blundell, 2006). However, in an environment dominated by hyper-palatable and energy-dense foods, the hedonic system seems to sometimes interfere with the homeostatic regulation by increasing the motivation to eat, decreasing the inhibitory satiety signals and forcing the intake to exceed the energy limits (Finlayson, Finlayson, Dalton, & Dalton, 2012). Furthermore, different dimensions such as genetic, metabolic, physiological and psychological factors - which form an integrated psychobiological system (Figure 1.3) - could all influence the hedonic aspects of an individual and cause the observed variations that exist among individuals. It has been shown that this integrated psychobiological system consists of both homeostatic and hedonic aspects of appetite that function collaterally to guide the human eating behaviour (Blundell & Finlayson, 2004; Lutter & Nestler, 2009).

Recently, significant progress has been made in understanding the hedonic system's components of "liking" and "wanting" foods, and in calculating their measurements.

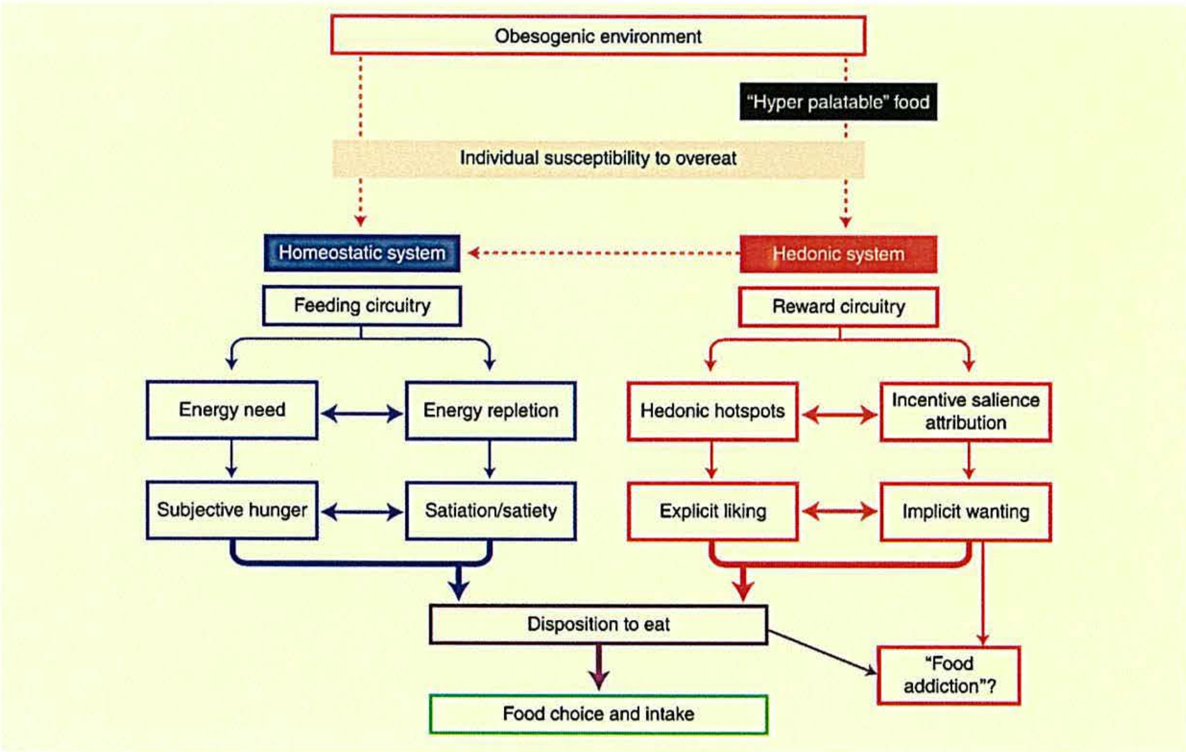

Figure 1.3. Illustrates the roles played by the hedonic system and homeostatic system in prompting overconsumption within an "obesogenic environment". The individual's susceptibility to overeat interacts with the highly palatable food which leads to the activation of the food hedonic process 'wanting ' and 'liking'. The hedonic process motivates eating and decreases inhibition by satiety, thus processing outside the normal regulation of homeostatic system. Reprinted and modefied from Finlayson et al. (2012).

1.4 "Wanting" and "Liking" - the Psychological Components of Reward

A considerable amount of appetite researchers assumes that the pleasure derived from eating and hedonic responses to particular foods are factors in driving obesity (de Graaf et al., 2005; Mela & Rogers, 1998; Nasser, 2001).The increase in food consumption could therefore be driven by pleasure not just the need for calories (Lowe & Butryn, 2007, Finlayson, King, & Blundell, 2007). However, a lot of studies in this field do not necessarily differentiate between behavioural aspects, physiological aspects, and cognition (Mela, 2006). More recently, emphasis has been placed on the importance of differentiating between the two essential components of reward: "liking" - the pleasure enjoyed as a result of food stimulating the oro-sensory system, and "wanting," incentive salience, or remedying the lack of something desirable and necessary (Berthoud, 2004; Blundell & Finlayson, 2004; Mela, 2001). Mela (2006) also proposed additional terminology that could help capture different types of motivation that can guide human food choices. He distinguished between liking, desire and preference. Liking refers to the hedonic value or palatability; the anticipation of pleasure the food will provide. Desire pertains to the intrinsic motivation to eat that is imminent. Preference can be described as a mixture of intrinsic and extrinsic motivational factors and can also include the cost of food, its availability and convenience (Mela, 2006).

Until recently, reward was believed to be a process in which dopamine transmission plays a major role. Yet, there are other mechanisms which play a part in the rewarding process and are known to be separable processes with different substrates (Berridge & Robinson, 2003). Berridge and Robinson (2003) identified these mechanisms as the three components of reward: motivation ('wanting'), emotion or affect ('liking'), and 'learning' as the main process. All these elements have conscious (explicit) and unconscious (implicit) components which require specific neural structures. This new conceptual approach of brain reward system focuses on affect and motivation ("liking' and 'wanting") as essential components that can contribute to our understanding of human eating behaviour (Finlayson et al., 2007). Huge efforts to theoretically and neurophysiologically explain these two components have been made by many researches (Berridge 1996, 2014; Winkelman & Berridge, 2003). Despite the lack of measurement and operationalisation of "wanting" and "liking", recently, some progress has been made trying to clearly distinguish "wanting" from "liking" (Mela, 2006). "Liking" can be measured by observing and assessing hedonic and aversive behavioural reactions that manifest as specific facial expressions across different species (Finlayson, King, & Blundell, 2007). Measuring "wanting" is not as unequivocal. It cannot be captured by solely looking at the individual's appetite drive or general non-specific desire for food, and it also needs to be distinguished from other appetitive processes such as needing. It consists of sensory and/or cognitive processes and pertains to the anticipatory phase of reward seeking behaviour (Finlayson, King, & Blundell, 2007).

Some primary reward-directed behaviours, such as eating and mating, have been considered essential for the survival of the species. It has been suggested that different animals therefore probably share a core set of brain regions where different types of reward are processed (Sescousse, Redouté, & Dreher, 2010).

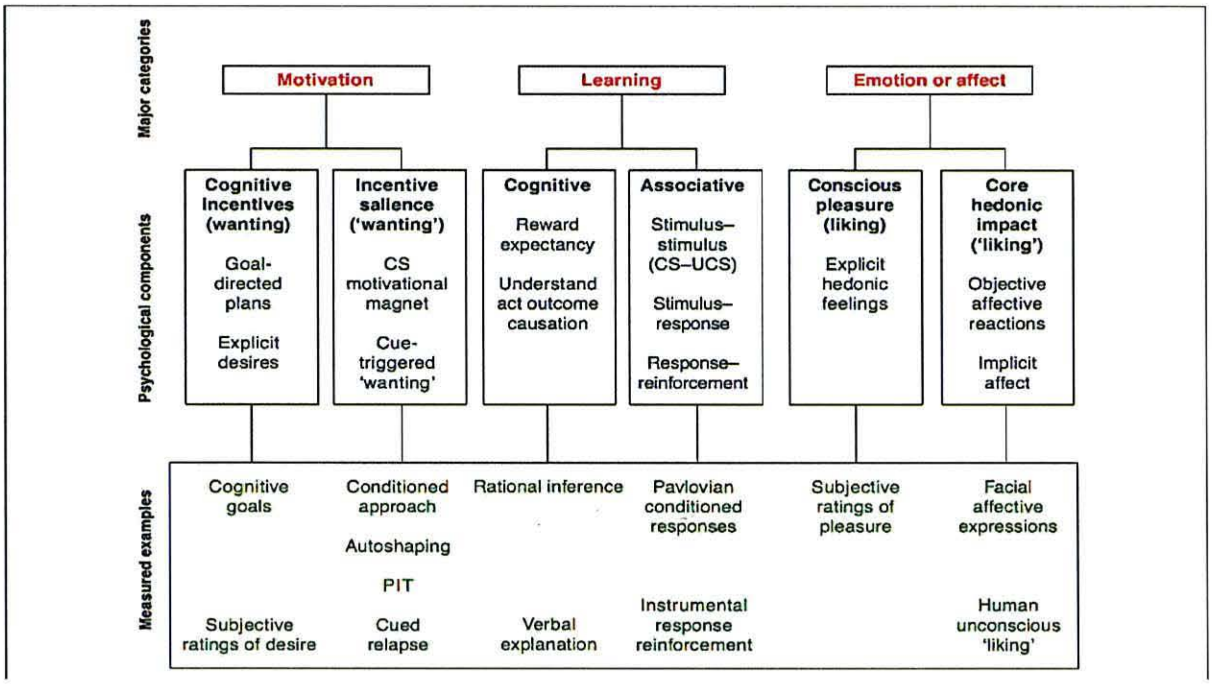

Figure 1.5. Reward components and how to recognize them. The categories of learning, motivation, and emotion or affect categories (top, in red) each contain different psychological components as shown (middle boxes, in blue). Both explicit and implicit psychological processes are unconscious in the sense that they can operate at a level not always directly accessible to conscious experience (implicit incentive salience, habits and 'liking' reactions) modified from (Berridge & Robinson, 2003)

To examine the sensation of "liking", researchers use transgenic mouse models alongside evidence derived from drug addiction studies (Berridge & Robinson, 2003;

Cannon & Palmiter, 2003; Peciña, Cagniard, Berridge, Aldridge, & Zhuang, 2003). According to characteristics or orofacial expressions of decerebrated (Grill & Norgren, 1978 a) and anencephalic rats (Steiner, 1973) to sweet taste, Berridge and Robinsons (2003) showed that the forebrain is not the only area in the brain associated with hedonic influence or liking of a pleasant trigger. They refer to these expressions as implicit affects and to the psychological process as 'liking'.

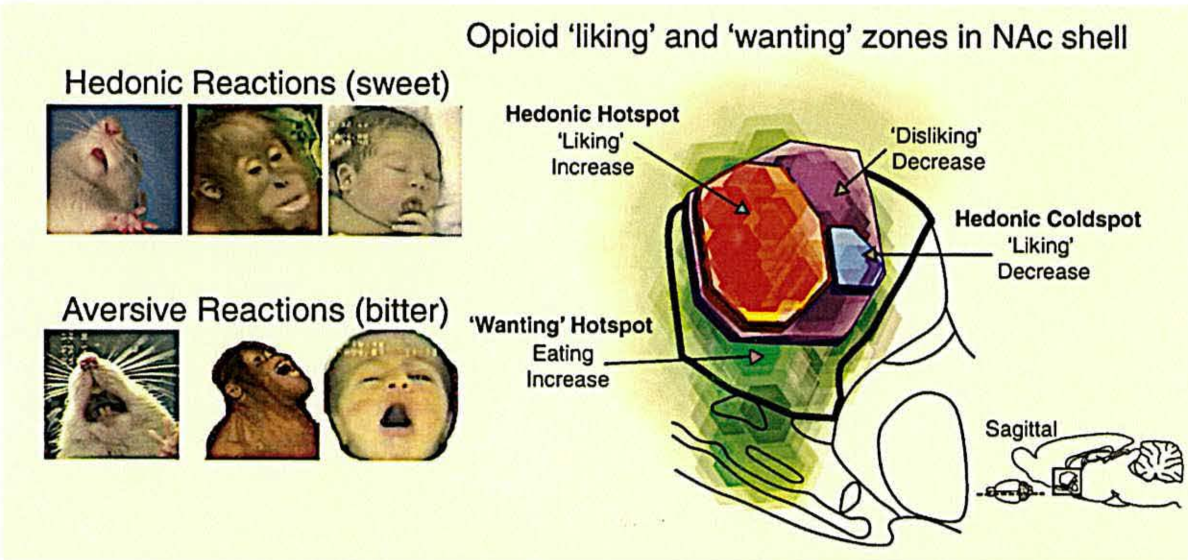

Figure 1.6. Reaction and nucleus accumbens hotspot map. The homologous reactions of human newborn, rat and orangutan to dislike bitter taste or like sweet taste. Reprinted and modified from (Smith et al., 2010) based on data from (Pecina:2006).

1.5 Explicit and Implicit Components

It appears that 'conscious' liking and 'conscious' wanting have their implicit equivalents that can operate on a level that is not conscious (Berridge & Robinson, 2003). These implicit components have an associated brain activity and form an unconscious core. In order to understand human eating behaviour, it is important to study both explicit and implicit components of affect and motivation (Finlayson et al., 2007).

Explicit or conscious liking manifests as hedonic feelings and sensory pleasures that accompany ingestion of palatable food. Implicit liking, on the other hand, can produce subjective reactions without the person being aware of their origin (Finlayson et al., 2007). Explicit wanting can be observed as a desire or intent to obtain specific food (Finlayson et al., 2007). The subject consciously desires an outcome that is represented cognitively (Berridge, 2004).

In contrast, implicit 'wanting' causes objective reactions in the subject through the incentive salience of external stimuli (Finlayson et al., 2007). Since implicit 'wanting' can sometimes produce objective reactions independent of any subjective experience, it may have a greater influence on eating behaviour than does explicit 'wanting' (Berridge, 2004). For example, Wyvell and Berridge (2000) showed that injecting amphetamine into the rats' nucleus accumbens can trigger excessive pursuit of reward (sucrose). When previously trained rats had their dopamine reward system activated, their sucrose-associated lever pressing increased without being reinforced by sucrose or an irrelevant cue. The authors concluded that cue-triggered incentive salience for reward can be potentiated (or become irrational) without the primary or secondary reinforcement. Furthermore, hedonic impact as measured by taste reactivity (liking) was not increased at doses that increased the wanting for sucrose. In the previous example, not only was the implicit 'wanting' of a reward greater than its explicit 'wanting', but the degree of 'wanting' was also out of all proportion to the extent of its expected 'liking' (Wyvell & Berridge, 2000). Finlayson et al., (2007) summarize that the core processes of liking and wanting are connected – there is an association between explicit "liking" and explicit and implicit "wanting", and also between implicit "liking" and implicit "wanting", which can influence ingestive behaviour without the individual's conscious awareness.

1.6 Homeostatic Control System and the Role of Genetic and Environmental Factors – Implications for Reward

Adipocyte homeostasis and appetite regulatory neural networks have been identified as important pathways for maintaining healthy weight (Friedlander et al., 2010).

Several genes on these pathways have been associated with obesity, namely leptin, leptin receptor, neuropeptide Y2 receptor and peptide YY. Leptin gene expression and leptin resistance, which is associated with the expression of leptin receptors, have previously been linked with obesity in humans and animals (Farooqi et al., 2002, Sader Nian & Liu, 2003). Some investigators assumed that leptin treatment could prevent obesity as leptin was associated with lower food intake and higher energy expenditure (Benzler et al., 2013; Roujeau, Jockers, & Dam, 2014). However, the treatment was mostly unsuccessful, as low circulating levels of leptin are more effective at stimulating food intake, than are high circulating levels at reducing appetite (Banks, 2003; Heymsfield et al., 1999; KG, 2002; Schwartz et al., 2003).Furthermore, most of the obese people who were treated already had high circulating leptin levels and they developed the so called 'leptin resistance' (Roujeau et al., 2014). Satiety hormones such as leptin did not evolve for the purpose of preventing obesity. In fact, given the environment in which most vertebrate evolution occurred, an overly strong satiety mechanism would have been disadvantageous. Often, individuals who are obese nevertheless have normal function in terms of homeostatic control (Berthoud, 2004; Berthoud, 2006). Some authors suggest that environmental influences derived from overabundance, and other lifestyle factors, may be responsible for overriding it. Food-related environmental factors can influence the regulatory system and different brain systems have been identified that deal with environmental factors (Berthoud, 2004; Berthoud, 2006). The massive neural systems of appetite and reward can be stimulated by ubiquitous commercial influences, resulting in increased food intake. Moreover, the decrease in energy expenditure, which is a result of a more sedentary lifestyle, means that for many genetically predisposed individuals, the total energy intake is too high for their homeostatic mechanism to regulate (Benoit, Clegg, Barrera, Seeley, & Woods, 2003; Petrovich, Setlow, Holland, & Gallagher, 2002; Tordoff, 2002). It has been suggested that reward can sometimes override the processes of homeostatic regularity system. According to Berthoud (2004), recognizing the role of reward is essential if obesity is to be successfully tackled by drug therapy or by creating behavioural strategies.

1.7 The Separation of "Wanting" and "Liking"

The brain system of “wanting” could sometimes induce the intake without increasing the hedonic “liking”. Berridge et al., (2010) referred to “wanting” as the process of “incentive salience, or motivation for reward typically triggered by reward-related cues” (p.45). (Figure7). They described “wanting” as a process that usually affects the food consumption plus is involved in much more. The incentive salience could be described as a mesolimbic pathway for perceptions of particular stimuli and images in the brain, especially stimuli that are linked to specific rewards, even if this is the Pavlovian cue for the reward. The incentive salience converts the image of food into an attractive and desirable one, catches the attention of a person and makes them want to obtain food. For example, it is the incentive salience that attracts someone’s attention and activates the thoughts of eating when the smell of cooking comes out of the kitchen. The “wanting” or incentive salience is different from the more cognitive craving indicated by the ordinary word, wanting (without quotation marks). Berridge et al. (2010) reported that “wanting involves declarative goals or explicit expectations of future outcomes, which are largely mediated by cortical circuits” (p.47).

The food cue itself is not very strong, however, it is important. The influence of a cue on incentive salience depends on the state of mind and previous links to food reward (Figure 1.7). “Wanting” is created by synergistic interactions between the present neurobiological state and the existence of food or its cues. The food cue together and combined with the mesolimbic activation (physiological hunger) creates a synergy that is motivationally compelling and is greater than any of the two components in isolation (Zhang, Berridge, Tindell, Smith, & Aldridge, 2009). The motivating strength of the food cue may vary between individuals depending on their brain characteristics, and it also depends on whether an individual is hungry or not (Berridge et al., 2010).

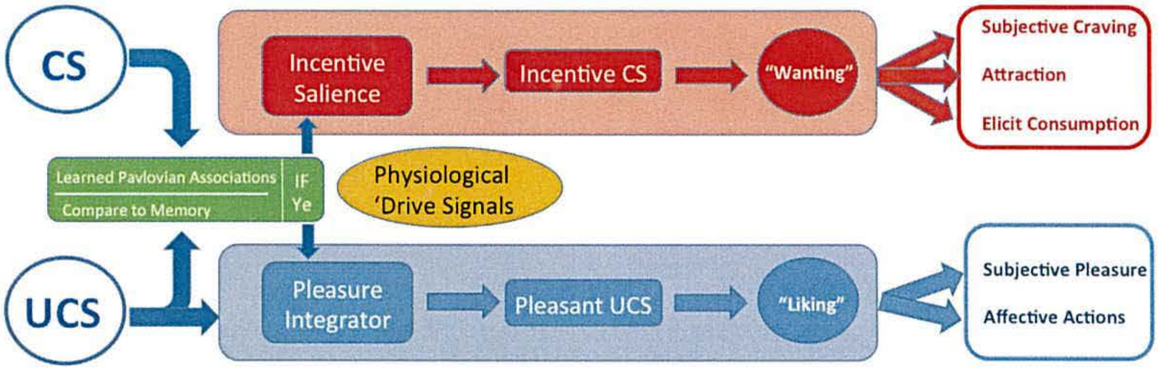

Figure 1.7. Incentive motivation model.

'Wanting' (incentive salience) and 'liking' (hedonic reward and pleasure) are separated. The physiological hunger acts as a driver that affects the 'wanting', and "liking' is stimulated by the food taste. Satiety, however, dampens the food cues. Modified from (Berridge et al., 2010).

1.8 Producing "Wanting" without "Liking"

Studies have shown that "wanting" can get enhanced alone without enhancing the hedonic "liking" for the same reward, and it has been suggested that incentive salience could exist as a distinct entity (Berridge et al., 2010). It might be possible that obese people crave food without liking or reward. This enhanced "wanting" without "liking was discovered by Berridge and Valenstein two decades ago in an animal study of eating where the lateral hypothalamus in rats was evoked by electrical stimulation (Berridge & Valenstein, 1991). Previous experiments on rats had suggested that the animals become excessively motivated to eat if their lateral hypothalamus got activated by an electrode (Valenstein, Cox, & Kakolewski, 1970). This type of activation included mesolimbic dopamine release (Hernandez, Rajabi, Stewart, Arvanitogiannis, & Shizgal, 2008). Dopamine activation is usually evoked by pleasant foods, hedonic rewards and reward cues (Di Chiara, 2002; Hajnal & Norgren, 2005; Montague, Hyman, & Cohen, 2004; Norgren, Hajnal, & Mungarndee, 2006; Roitman, Wheeler, Wightman, & Carelli, 2008; Small, Zatorre, Dagher, Evans, & Jones-Gotman, 2001).

The study by Berridge and Valenstein (1991) aimed to answer the question if rats truly "wanted" to eat more because of an increased hedonic influence as previously hypothesized. This was not confirmed. While the activation of the hypothalamic electrode made the rats eat at twice the rate of their average intake, their "liking" reactions were not enhanced (Berridge & Valenstein, 1991)(Figure 3). Instead of observing increased "liking" reactions (such as lip licking), the electrode only enhanced "disliking" reactions (such as gapes) to the taste of sucrose. It appeared that sucrose became slightly unpleasant during the phase of voracious eating. This and other research into the dissociations of "wanting" and "liking" point to the need to identify separate neural substrates for each when studying appetite control and obesity (Finlayson et al., 2007). There is no clear evidence describing this procedure in humans as yet (Berthoud et al., 2010)

1.9 Understanding Obese Humans' "Liking" and "Wanting" Behaviour towards Food

Few empirical studies have separated the desire to consume food (wanting) from the pleasure experienced during eating (explicit liking). However, a distinction of the conscious (explicit) from the unconscious (incentive salience) aspects of 'wanting', and the way this 'wanting' is reinforced by food stimuli and other hedonic rewards, may explain the differences in the eating behaviour of lean and overweight individuals (Berridge, 2004, p. 196). In particular, physiological and behavioural evidence can capture these subtleties of conscious, everyday experience and can, therefore, supplement traditional categorisations or ratings of "liking" or "desire to eat".

Greater sensitivity of obese individuals to food reinforcement was first noted in the 1960s in a study on "external" eating (Schachter, 1971; De Graaf, 2005; Herman et al., 2005; Lowe & Levine, 2005). This study found that obese subjects frequently experienced a higher appetitive response to the palatability of food and other food cues. Although factors such as dieting, hunger, weight concern and separating cause from effect were not controlled, these results are consistent with those of subsequent behavioural and physiological studies that were designed using more sophisticated frameworks based on cognitive and neurophysiological methodologies (Berthoud, 2004; Wang et al., 2004; Herman et al., 2005; Lowe & Levine, 2005; Volkow & Wise, 2005).

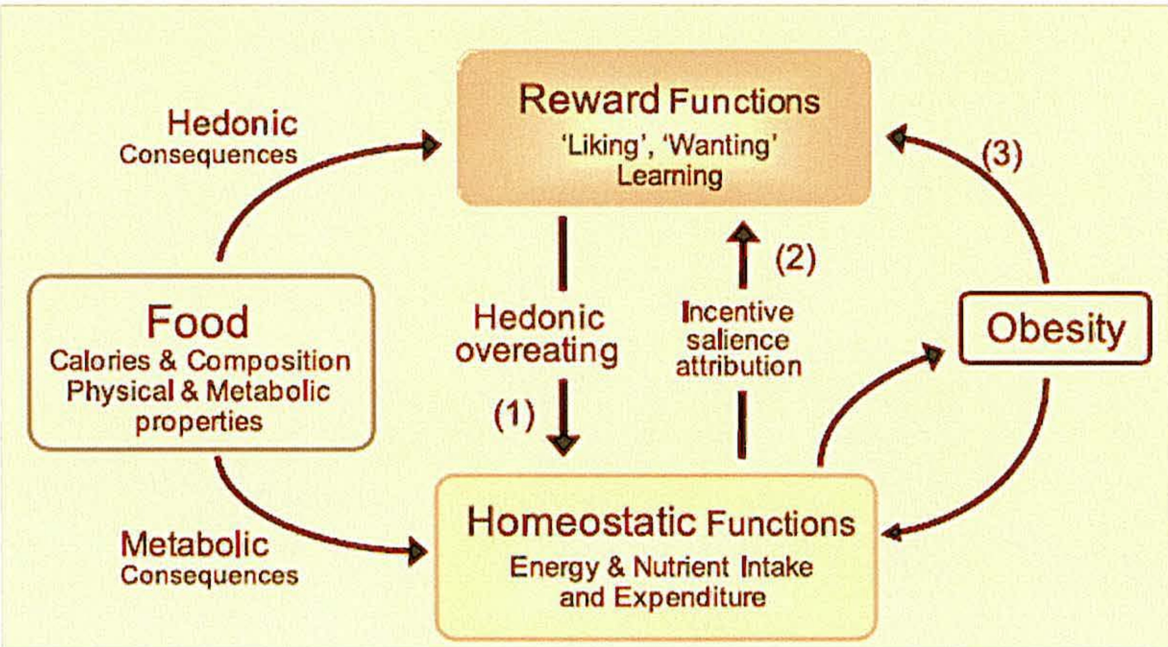

Figure 1.4. The relationship between metabolic and hedonic controls of food intake and energy balance. The metabolic consequences of food are regulated by homeostatic functions and the hedonic consequences by reward functions. Hedonic and metabolic consequences are interdependent: the hedonic value of food changes caloric intake (*1*), and the metabolic status changes hedonic processing (*2*). Obesity is associated with altered reward functions, but it is not clear whether these changes are the cause or consequence of obesity. Changed reward functions could cause obesity via increased intake of calories or fat (*1*), or alternatively, could result from consequences of the obese state (*3*), or could be a combination of both. Reprinted and modified from (Berthoud, Lenard, & Shin, 2011).

In obese individuals, the presence of food cues is also associated with a greater preparedness to work for a food reward (Johnson, 1974) and, in obese women, it has also been associated with a significant increase in blood flow to the right temporal and parietal cortices (Karhunen, Lappalainen, Vanninen, Kuikka, & Uusitupa, 1997). Interestingly, despite these physiological and behavioural differences, hedonic ratings for foods were similar between the obese and the non-obese groups. Hence, these results demonstrate an important distinction between the reinforcement and hedonic values of food. For example, Saelens and Epstein (1996) used a computer task to show that the reinforcement value of food rewards is not only greater in obese than lean women, but is greater than the reinforcement by non-food rewards of equal hedonic value. Similar results were found for smokers, where energy intake was more strongly associated to food reinforcement than to 'liking' (Epstein et al., 2004).

Recently, advances have been made to resolve the inconsistencies thrown up by the literature concerning the impact either being sated or being hungry has on the desirability of food (Yeomans et al., 2004). For example, food deprivation has been found to affect the reinforcement of food's value as against its hedonic value. A comparison between deprived and fed non-obese female participants showed that food became more reinforcing for the deprived group, however, the hedonic measurements remained comparable for both groups, which suggests that hedonics and reinforcement are two separate processes (Epstein, Truesdale, Wojcik, Paluch, & Raynor, 2003). Finally, 'liking' and 'wanting' in obese subjects are expected to be distinguished by new behavioural tests, such as those developed by Finlayson et al. (2005).

To conclude, it is becoming increasingly accepted that obese people overeat in response to stimuli that are not related to homoeostatic control, and which do not imply a deficit in their homoeostatic systems for maintaining energy balance. Orosensory stimulation and explicit liking of foods both receive extensive attention, yet weight differences cannot be clearly linked to differences in hedonic experience or to variations in the explicit pleasure gained from eating.

Mounting evidence from behavioural studies and neurophysiological research may unravel what otherwise appears to be a discrepancy, by differentiating between the hedonic value (''liking'') and incentive salience (''wanting'') , and in the process offering fresh insights into obesity and excessive consumption.

Figure 2 addresses the question ''What makes us want to eat what we want to eat?'' by applying the concepts just discussed. It incorporates an understanding that the conscious awareness at a specific moment of wanting to eat a certain food is produced by balancing: (1) our physiological state, and triggers including, *inter alia*, thirst and hunger; (2) the pleasure expected to be gained by eating (heavily influenced by associations based on past experience); and (3) external triggers and associations (again, normally the product of past experience, and affected by cognitive elements combined with factors we not may consciously recognise). The desire to eat in a given situation may also be suppressed or stimulated by inputs that reflect these various influences (Mela, 2000).

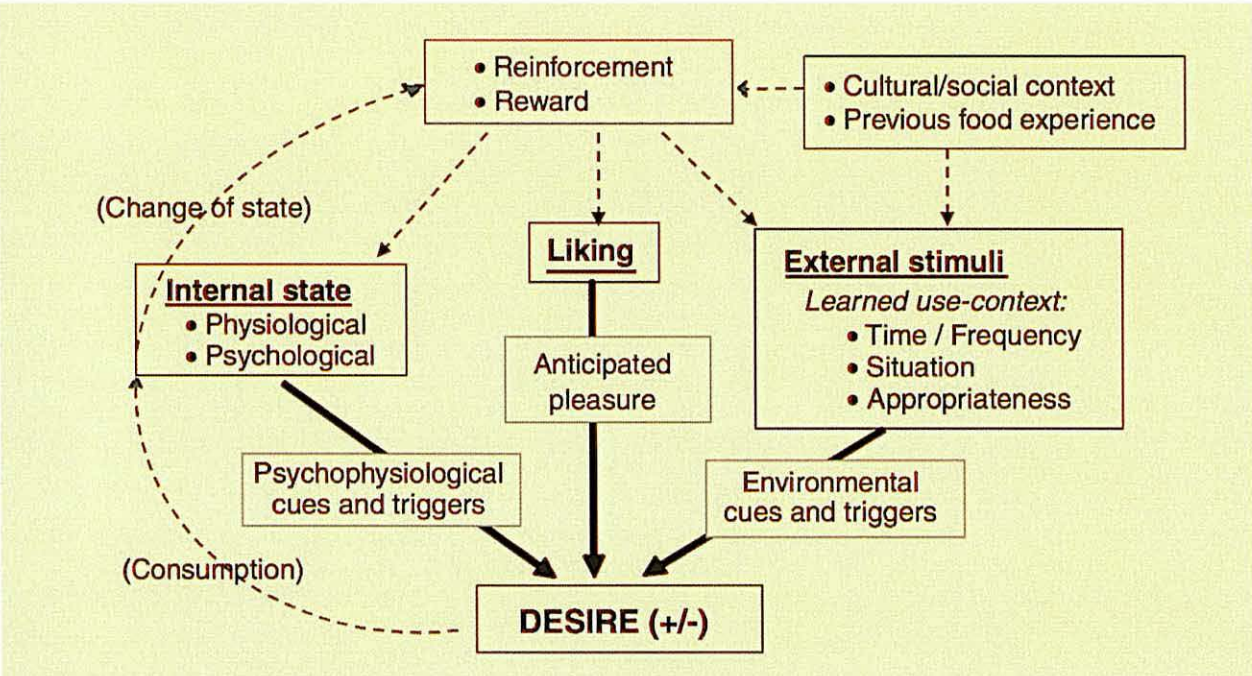

Figure 1.8. Illustration of the operational schematic of the effect of internal state (combined physiology and psychology), liking (pleasure) and external triggers (use-context that has been learned) in activating food cravings in daily life. Proximate drives shown by solid lines; dashed lines are underling process. Modified from Finlayson et al (2007) and Mela (2001).

1.10 Implications for Obesity and Weight Gain

Many authors believe that understanding the interactions between the hedonic and homeostatic processes involved in human appetite is a key factor to explaining obesity (Blundell & Finlayson, 2004; Erlanson Albertsson, 2005; Nasser, 2001; Yeomans, Tovey, Tinley, & Haynes, 2004). Nevertheless, the role of reward in the aetiology of obesity is still not well understood. There are some studies that investigated people's variability in sensitivity to reward (STR). Using the Physical Anhedonia scale (L. J. Chapman, Chapman, & Raulin, 1976), Davis et al. (2004) measured the capacity to experience reward in lean patients, those who were overweight, and the obese. The relationship discovered formed an inverted U; overweight patients scoring higher than both obese and normal weight patients. In a similar way, Franken and Muris (2005) showed that STR has an association with BMI and with food cravings. Moreover, STR has a significant relationship with the brain's response to foods that are appetising, as demonstrated by relevant regions of that organ being activated (Beaver et al., 2006).

The individual reward variation could lead to overconsumption which is in many ways related to homeostasis. Finlayson et al. (2007) summarized the many possible explanations for obesity in relation to "liking" and "wanting" components of eating. (1) Some people might be prone to an exaggerated hedonic response to food and therefore enjoy palatable food in greater amounts and with greater frequency compared to their peers. Studies looking at neuroimaging sometimes find neural activation that is more extensive in certain brain reward spots after meal intake in weight gaining individuals in comparison to control individuals who are lean (Gautier et al., 2000; 2001). In contrast, (2) some individuals might experience reduced levels of pleasure from foods. To compensate, they might eat more palatable foods to achieve an optimal level of stimulation. Salons and Epstein (1996) came to a similar conclusion when they compared normal weight individuals to obese people and found that the latter required more effort to like food. Another option, which links "wanting" and "liking", also suggests that (3) some individuals react more to food cues and have a greater motivation to pursue these cues. This is also linked to (4) the lack of ability to resist the motivation to eat, which leads some individuals to engage in non-homeostatic eating. Finally, it appears that (5) some people habitually choose foods that promote overconsumption such as energy-dense foods which, in combination with other factors, can lead to an energy surplus and gaining weight.

1.11 Measuring Hedonic Components

Converting the hedonic components of "liking" and "wanting" into measurable behavioural operations involves a lot of challenges. For dissociations to be detected, an acceptable procedure must avoid confusing the components (Finlayson & Dalton, 2012a). Finlayson and Dalton (2012a) suggested that numerical scales, visual analogue scales and similar psychometric techniques should be developed to measure the explicit food "liking" and "wanting". Explicit "liking" for a particular food is frequently measured using questions along the lines of "How pleasant would tasting this food be at this moment?" or "How pleasant does this food taste?" Alternatively, assessing explicit "wanting" would involve such questions as "How strong is your desire to eat this food?" or "How much do you want this food?" (Finlayson & Dalton, 2012a). On the other hand, with subjective techniques there is a potential lack of accuracy that comes with self-reporting and there are methodological issues that derive from it. However, Finlayson and Dalton (2012a) predicted that these techniques could show sufficient sensitivity even for subtle experimental use, if they are carefully applied, and could be used to predict intake behaviours.

1.12 Measuring Liking

"Liking" is often characterised as an alteration in affect seen by techniques for analysing rats' taste reactivity (Grill & Norgren, 1978a). Taste reactivity test has been conducted as an objective measurement of hedonic response, using the quantifying discrete orofacial affective responses to different tastes (Steiner, Glaser, Hawilo, & Berridge, 2001). Behavioural neuroscience studies were originally conducted on rats (Grill & Norgren, 1978a; 1978b), however, even earlier, the affective reactivity test had been conducted on human infants (Steiner, 1973). Responses to palatable and un-palatable tastes in both animals and humans indicated that orofacial reactions are significantly homologous, with positive hedonic 'liking' reactions (e.g. tongue protrusion, lateral tongue protrusions and paw licks), and negative 'disgust' reactions (e.g. gapes, head shakes and chin rubs) (Jankunis & Whishaw, 2013; Steiner et al., 2001).

Patterns of taste reactivity have been considered a relatively pure indication of affect (Berridge, 2000,) since they are capable of being separated from taste's sensory properties. Moreover, the desire to eat can also be separated from taste reactivity patterns (Berridge & Valenstein, 1991; Berridge, Venier, & Robinson, 1989) and the latter often represent subjective human palatability ratings (Finlayson et al., 2007).

In humans, most of the investigations of the reward processes usually include subjective measurements of liking. However, some studies have shown that such introspective scoring has its limitations. Finlayson et al. (2007) report that subjective scorings or liking ratings and short term exposure constitute the most common tests. Although these types of tests are easy to conduct, they are significantly different from the free-living eating situations and do not correspond with the quantities of food and combinations of foods and drinks consumed in day to day life. When investigations are conducted in laboratories and include only a brief exposure test, they purportedly result in a biased estimation of food palatability (Bellisle, Lucas, Amrani, & Le Magnen, 1984; Lucas & Bellisle, 1987; Monneuse, Bellisle, & Louis-Sylvestre, 1991; Pérez, Dalix, Guy-Grand, & Bellisle, 1994; Zandstra, de Graaf, van Trijp, & van Staveren, 1999). Moneys et al. (1991) showed that ad libitum tests are the best for consumption whereas taste-and-spit tests are the least helpful. These results were supported by other studies that found "liking"' rating alone insufficient to predict subsequent consumption (Bellisle & Le Magnen, 1980; Hellemann & Tuorila, 1991). Also, it appears that short exposure (rating after one bite) does not always correspond with longer exposure (rating post-meal). This suggests that the time point of measuring the "liking" component plays a significant role and can influence the findings (Zandstra, De Graaf, Mela, & Van Staveren, 2000).

Some of the other factors to consider when assessing "liking" include repeated exposure to food, satiety levels and previous eating events and experiences (Spiegel, Shrager, & Stellar, 1989; Zandstra et al., 2000). Zandstra et al. (2000) conducted an experiment that assessed the pleasantness of food and the desire-to-eat over 5 consecutive days. Their study showed that the intake of sandwich made out of bread that was initially perceived as low in pleasantness, changed over time. With repeated exposure, study participants increased their intake of less preferred bread and their fullness ratings changed as well. The authors concluded that the relationship between pleasantness of food and intake can be altered over time. The change in circulating gastrointestinal hormones, which get released post-prandially, can also change the individual's desire to eat certain foods that were desired before the meal. The modulation of gut hormones has already been explored as a possible therapy for obesity (Stanley, Wynne, McGowan, & Bloom, 2005).

In summary, the findings and observations of current measurements of "liking" indicate that although rating of subjective liking is essential for the reward process investigations, laboratory tests are limited and do not always reflect the free-living reality of everyday lives nor do they include the various factors that can influence "liking". There have been discrepancies between the findings of laboratory test and some free-living studies (Finlayson et al., 2007). Measuring subjective "liking" is still insufficient and more efforts are required to develop a valid instrument for measuring hedonic responses in free-living subjects (Finlayson et al., 2007).

1.13 Measuring Wanting

If "liking" is an alteration in affect as seen by techniques for analysing taste reactivity linked with food reward, then "wanting" is usually quantified by alterations in the propensity for intake standing apart from changes in "liking". A measurement could contain at least a part of "wanting" where the subject needs to react with its surroundings to trace a familiar food stimulus (Finlayson et al., 2007). It is important, however, to acknowledge that generally, wanting is not sufficiently described by a desire that is non-specific or an appetitive drive to eating. Wanting is assumed to be a reaction and involve a process of actively assigning value to perceived or represented events in which cognitive inputs and sensory inputs are altered by an appealing and desirable object (Berridge, 1996). Therefore, wanting implies regulation by cognitive and sensory effects that separate it when compared to such other appetitive actions as needing. "Wanting" is more than simply a driver; there is also a directional component to it. Thus, assessing a "wanting" independently from a non-particular impulse to eat could be difficult, especially when separation from "liking" is also required (Berridge, 1996). Hence, the analysis and research of food craving could reveal a useful platform that would give more explanation of this system (Pelchat, 2002; Robinson & Berridge, 1993). That said, a more satisfying measure of wanting addresses the anticipation or instrumental element of reward chasing behaviour.

Expressing an implicit "wanting" for food is something many people find challenging. On the other hand, they are successful when predicting or explaining their explicit "liking" for food. The difficulty stems from expressing motivational aspects of reward implied by "wanting" (Finlayson et al., 2012). Thus, steps that indicate a motivation driven response to triggers or stimuli involving food could include one or more elements of implicit "wanting". The less conscious the reaction, the nearer we are to measuring behaviour that indicates "wanting" with no influence of subjective processes. Since "wanting" requires not only a force but also a target with direction, it is essential to consider that it may not be sufficiently described by a desire for food that is nonspecific (Finlayson et al., 2012).

Various techniques have recently been developed to assess the implicit "wanting". Such techniques depend on an instrumental response (e.g. button and mouse click) to reflect food cues. These techniques are classified into two categories. The first category is operationalised "wanting" which measures food's reinforced value, or the extent of the effort made by an individual to access food rather than an alternative reward (Epstein, Leddy, Temple, & Faith, 2007). The next category is dependent on the time response to stimuli or cues; techniques like Visual Probe, Stroop and Stimulus response compatibility tasks assess response time following exposure to a certain food rather than another category of food (Nathan et al., 2012). The results are impacted by the food "approach bias" which influences the speed of response.

1.14 Dissociating Food "Wanting" and "Liking" in Humans

As long as hedonic driven intake in humans is modulated by dissociable "wanting" and "liking" , it is an essential requirement to be able to objectively quantify the element of reward in terms of investigating the separate contributions of these two components. Several tests and tasks have been adapted and developed to measure these components, however, it has been asserted that measuring "wanting" separately from "liking" is a very challenging task. In order to measure food "liking, a linear scale was adapted by

Finlayson, King and Blindell (2007a) to measure how pleasant it would be to experience a mouthful of particular food. Subjects repeatedly had to choose between two items of food they wanted to eat most, which translated into comparative preferences determined by levels of "wanting". The authors recorded food "wanting" and "liking" after each meal and before each meal, and no alterations have been found in the "wanting and "liking" components of their meal intake. When hungry, subjects "wanted" savoury foods that were high in fat rather than low-fat savoury foods. There was not any appreciable difference in "liking" of these foods recorded. Also, the food deprived subjects liked foods that were sweet and high in fat, more than foods that were sweet but low in fat, with no appreciable difference in the "wanting" of such foods. The opposite findings were obtained when subjects were sated. In a sated situation, subjects preferred low-fat savoury choices over high-fat savoury choices, and liked sweet foods that were low in fat. In a later study by Finlayson et al. (2008), these findings were not replicated.

With meal intake, the changes of "liking" were not dissociated completely from those in "wanting". Finlayson, King, and Blundell (2007) stated the following conclusion "… the findings of present study provide support for the conceptualisation of preference (in terms of a behavioural outcome) as containing… elements of liking and wanting" (p.1000). This means that the relative preference measurement proposed by Finlayson et al. (2007) is not applicable to measuring pure "wanting".

In a different study that measured "wanting" food, subjects had to perform a certain instrumental response to obtain food reinforcement (Epstein,Truedale, Wojcik, Paluch, & Raynor 2003; see also Mela, 2006). Subjects participated in a game to get points in order to trade them for a similiar amount of snacks (e.g. chocolate bar or chips). Subjects used a joystick, and the computer provided them with a feedback of their score. During the task, the subjects had to respond and points denoting snack reinforcement were awarded until the end of the task or until the subjects decided to stop. Those who were less well endowed were more motivated by food and worked more extensively for their snacks. Nevertheless, deprivation was not a significant factor affecting the "liking" scores for snacks such as chocolate flavoured milk, lemon juice and water. Epstein and colleagues (2003) concluded that there is a disconnection between "liking" and "wanting", as displayed by the dissociation between hedonic preferences and reinforcing value of food.

The dissociation appeared to stem from the fact that "liking" was assessed for drinks and "wanting" for snacks.

1.15 Obesity and Food Liking

Previous studies showed that obese individuals exhibit "normal" chemosensory functions like detection and recognition. However, they appear to like some particular tastes and aromas more than their lean peers (de Graaf et al., 2005; Mela, 2006). The relevance of the perception of texture (e.g. fat in food) has not been determined yet. It is difficult to characterise and control the physical properties of test food. Moreover, it has been noted that there is a large lack of appropriate terminology that could be used to describe sensations relating to texture (D. N. Cox et al., 1998).

Individuals with an increased obesity risk have been reporting greater liking for high fat food, and they also appear to choose to consume food that has higher energy density (de Graaf et al., 2005; Mela & Rogers, 1998; Nasser, 2001; Rissanen, Hakala, Lissner, & Mattlar, 2002). Nevertheless, the outcomes of these studies were not consistent, and there have been problems with the interpretation result or with study design, for example, control, presentation and choice of food stimuli (Salbe, DelParigi, Pratley, Drewnowski, & Tataranni, 2004). All previous methodological issues are considered more problematic when testing with examples of real, everyday foods. Moreover, the fact that lean and obese individuals usually experience different thoughts connected with food makes the experiment more compounded (Herman, Polivy, & Leone, 2005).

Laboratory experiments have revealed guaranteed results concerning the role hedonic responses play in obese subjects reacting to certain foods. The "liking" rating obtained with food lists (Cox et al., 1998) or when measuring intake of foods freely available (see Figure 1.9) were unsuccessful in proving that obese subjects select foods that are more pleasant (Mela, 2006). Additionally, findings of different food type ratings have been inconsistent, too (Mela, 2006). Also, longitudinal studies and cross-sectional experiments have not shown a real consistency in associations between food intake patterns and body mass index or obesity (de Graaf et al., 2005; Halkjær et al., 2004; Mela & Rogers, 1998; P, M, TI, & BL, 2001). Nevertheless, obese people appear to excessively consume foods that have greater energy density or volume content (Cox, Perry, Moore, Vallis, & Mela, 1999; Westerterp-Plantenga, Pasman, Yedema, & Wijckmans-Duijsens, 1996). These findings indicate an association that can be drawn between obesity and over consumption of food, possibly targeted at foods with high energy density. Interestingly, there does not seem be a higher degree of pleasure associated with orosensory experience of food in obese individuals compared to lean controls. Also, no increase on the "liking" component has been consistently reported for the former group. It has been suggested that further research in this field is required to better understand the phenomenon of obesity and its aetiology (Mela, 2006).

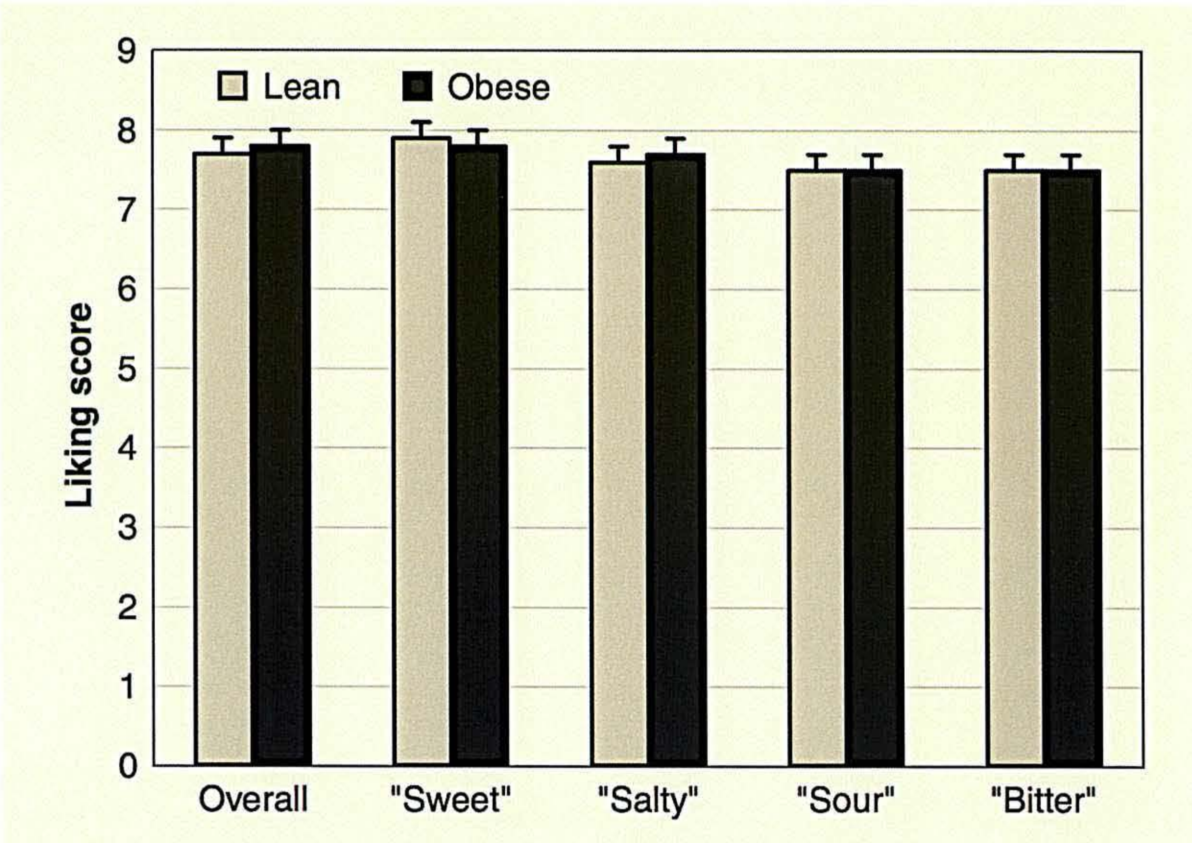

Figure 1.9. Mean liking scoring where (1 = dislike extremely) and (9= like extremely) food that chosen to eat freely.

Lean subjects (BMI <25 kg/m^2, n=41) and obese subjects (BMI>30 kg/m^2, n=35). Each food was classified by subjects according to the principle character of its taste. The groups did not differ appreciably. Result from Cox et al. (1999)

1.16 Aim of the Thesis

As obesity becomes a worldwide epidemic, investigators are debating the physiological and behavioural causes of weight gain. Overconsumption contributes to a positive energy balance in the body (Westerterp & Speakman, 2008; Swinburn et al., 2009), however, it is unclear whether the regulation of appetite in overweight and obese subjects is dominated by homeostatic/physiological responses or by hedonic/psychological responses of 'liking' and 'wanting' (Blundell & Finlayson, 2004).

Highly controlled laboratory and questionnaire-based research found that obese and lean people exhibit differences in their "wanting" and "liking" responses to food. However, due to creating specific environmental conditions, far removed from real life scenarios, the findings of these studies have limited applicability (Blundell et al 2005, Dykes et al 2004). Continuous patterns of 'wanting' and 'liking' have not yet been investigated in real life situations; therefore, the time dimensions of perception and action in eating behaviour are not well investigated and understood. These time patterns, or rhythms in perception, and their intensities ('wanting' and 'liking' of food) might be important for the understanding of the mechanisms of obesity and could contribute to the development of more efficient treatment methods.

To address this huge knowledge gap in our understanding of people's eating behaviours, chapter 2 aims to describe the development of a new smartphone application ('Mind Eating') which records and analyses continuous patterns of food "wanting" and "liking" in real life situations. Subjects use their mobile phones to score the intensity of their "wanting" and "liking" as well as to automatically record the timing of these events. "Wanting" here captures the hedonic (craving, reward expectations) and homeostatic (hunger, appetite) aspects, and 'liking' includes palatability, satisfaction (reward), and physiological response from the GI system. Moreover, eating events and their duration are also measured by this application.

To gain a deeper insight into the psychological drivers of overweight and obesity, chapter 3 reports the analysis of the continuous patterns of "wanting" and "liking" of food in real life situations and compares the data of obese individuals with lean matched controls. The initial hypothesis was that obese people would exhibit different food “wanting”, “liking” and eating patterns compared with lean controls. In addition, in chapter 3, a new method - “time series analysis” – is used for the first time on eating behaviour data to analyse time patterns.

Finally, chapter 4 documents a pilot study that investigated the effect of exercise on the physiological and psychological dimensions of eating behavior using the new smart phone application. In particular, time patterns, frequencies, and intensities of the hedonic responses of “liking” and “wanting” events are compared at baseline and post-exercise in sedentary lean and overweight/obese individuals (but not in physically-active or athletic ones).

CHAPTER 2

2. STUDY 1: DEVELOPMENT OF A NOVEL SMARTPHONE APPLICATION "MIND EATING" FOR ASSESSMENT OF 'WANTING' AND 'LIKING' IN FREE-LIVING PARTICIPANTS

2.1 Introduction.

Great efforts have been made in the field of neuropsychology to improve our knowledge of the reward system in the brain. Recently, the non-homeostatic or hedonic mechanisms (reward) became focal in the studies of energy balance and overconsumption (de Graaf et al., 2005; Finlayson et al., 2007; Mela & Rogers, 1998). . In the last decade, neurological research instigated by Kent Berridge (e.g. Berridge, 1996; Castro & Berridge, 2014) led to a framework proposing the hedonic components of the rewards system. The term 'Wanting' was used for one of the hedonic components known as the motivation or incentive salience component. The term describes the process that is typically triggered by reward-related cues. It contains a goal or explicit expectation of future outcomes (Berridge et al., 2010) . Functionally, it refers to the neural process that mediates the change in behaviour from ignoring an object to actively seeking it. The second affective or hedonic component is known as "liking" and refers to the result of a central process incorporating not only sensory properties, but also the individual's physiological state and associative history (Finlayson et. al, 2007). Identifying the two neural substrates for the "wanting" and "liking" components of reward has important implications for eating behaviour in humans. If reward is considered a paired process, the respective contribution of "wanting" and "liking" needs to be fully understood in the context of eating and behavioural change.

Obesity research, using behavioural and brain imaging studies, has shown that compared to lean individuals, obese people have a higher response to anticipatory "wanting" than to consummatory "liking" of food reward (Stice at al. 2009). Moreover, obese subjects show less activation in some reward areas of the brain during food intake and have lower D2 dopaminergic receptor density compared to lean participants (Volkow et al. 2008; Wang et al. 2001). The incentive salience theory suggests that obese people expect more reward/satisfaction from a particular food than the consumption of it will deliver (Berridge 2009). The highly controlled laboratory and questionnaire-based research, which showed that obese and lean people exhibit differences in their 'wanting' and 'liking' responses to food, had the disadvantage of creating specific environmental conditions far removed from real life scenarios (Blundell et al 2005, Dykes et al 2004). Finlaysons et al. (2006) claim that "direct study of these components in humans (i.e. by asking them in terms of liking and wanting to see how they feel) may not always be accurate or valid. In the case of 'wanting', problems are encountered when people fail to dissociate affective aspects from motivational aspects of the process (e.g. "It's pleasant, so I want it")."

In human research, most of the measures are visual analogue scales where judgments are marked along a line, anchored by statements at each end, or by numerical scales with discrete labels at the beginning and end or at each point. Likert scales are also commonly used where the subject is asked to evaluate a statement, usually with a level of agreement or disagreement (Sibilia, 2010). It has been suggested that individuals could be affected by subtle differences in questions or statements presented to them. For example, Rogers and Blundell (1990) described the variation in pleasantness scores depending on whether an individual scored the pleasantness of the taste of food or the pleasantness of eating that food. Moreover, these kind of measures can cause more challenges when "wanting" and "liking" are taken sequentially (Finlayson et al., 2007). If a subject is tempted to recognize them both in the same question, then the response could be adjusted to avoid dissonance and be consistent.

There are several areas of appetite research that would require more attention and could help explain some of the factors related to obesity. Not many studies explored how implicit and explicit attitudes towards food relate to weight gain. It appears that the subconscious (implicit) attitudes might be more important in the dynamics of eating behaviour, as demonstrated by Sartor et al. (2011). Their study found that implicit attitudes towards sweet foods were significantly higher in overweight and obese subjects.

Another limitation of previously conducted studies on food attitudes is also that they were often conducted in highly controlled environments or laboratories and did not reflect real-life scenarios, which makes their findings limited to specific environments and situations (Blundell et al 2005; Dykes et al 2004). Studies that would explore continuous patterns of "wanting" and "liking" in a free-living context are lacking (Gibbons et al., 2014). Moreover, brief exposure tests do not capture the Time dimensions and rhythms in perceptions, which remain poorly understood. Enhancing the understanding of the time component of eating could arguably help explain the mechanisms of obesity and assist in the development of novel treatment approaches to food disorders and addictions.

The advent of digital technology, among other thing, introduced novel ways of collecting data from larger samples. Smartphone applications are being increasingly used in research and health promotion (Stephens & Allen, 2013; Torous & Powell, 2015). Since mobile technology is ubiquitous, phone applications enable scientists to expand their pool of research participants and gather more relevant information, leading to new applicable solutions. Ethical and social issues concerning the use of digital technology in research and health promotion have been discussed, however, they remain inadequately addressed (Lupton, 2015). Therefore, it is important to maintain a critical stance when promoting the use of digital health technology for scientific purposes, especially when pervasive computing techniques are being employed (Lupton, 2015). The Mind Eating smartphone application was developed to address a huge knowledge gap in our understanding of people's eating behaviours. The application was designed to record and analyse continuous patterns of food "wanting" and "liking" in free-living participants. The application scores the intensity of 'wanting' and 'liking' and automatically records the timing and duration of eating and drinking events. We aimed to study both hedonic and homeostatic aspects of appetite and compare obese and lean participants. Both explicit hedonic components and homeostatic aspects (hunger, appetite) were targeted. "Wanting" encompassed craving and reward expectations as well as hedonic components; and "liking" referred to food palatability and satisfaction (reward).

We hypothesized that obese and lean individuals will differ in their "wanting", "liking" and eating patterns.

2.2 Aims of This Chapter

The objective of this chapter is to present the overall process of developing the Mind Eating smartphone application including the following:

1- Requirements and Specifications: to describe of software system to be developed. It lays out functional and non-functional requirements, and include set of use cases that describe user interactions that the software must provide.

2- Design : all the activities involved in conceptualizing, framing, implementing, commissioning, and ultimately modifying complex systems" or "the activity following requirements specification and before programming.

3- Implementation: describe the process of designing, writing, testing, debugging / troubleshooting, and maintaining the source code of computer programs.

4- Pilot study and evaluation : testing and evaluate the reliability and capability of the phone application and evaluate the its functionality.

5-Related Work and Discussion

6- Conclusion and Future Work

2.3 Requirements and Specifications

Our aim was to develop a smartphone application that assesses and measures the components of "wanting" and "liking" in free-living individuals. This section focuses on identifying the requirements of our (Mind Eating) application and specifications determined by the results of the requirement analysis. A detailed analysis has been performed to understand the problems and issues that the (Mind Eating) application should address.

, There is a huge lack of long-term studies that would investigate the dual aspects of food reward components and would not rely on laboratory, short-exposure tests (Berridge, 2004; Finlayson et al., 2007). To understand and measure the hedonic components "wanting" and "liking", it is important to dissociate the two components and use a reliable technique on free-living individuals. However, it has been recognized, that dissociating and converting "wanting" and "liking" into measurable behavioural components involves some challenges (Finlayson & Dalton, 2012a). Nonetheless, this approach might help explore some research questions related to food choice, appetite control and overconsumption (Finlayson et al., 2007).

When developing the application, we had to specify certain requirements, namely the functional requirements, the non-functional requirements, and other specifications related to the application. Factors such as availability schedule, development time, and other implementation aspects were also considered. The specifications covered the following feature requirements:

Friendly User Interface: A design with a simple and friendly user interface (UI), which would be consistent with the device was needed for this application. Apple's IOS human interface guidelines were carefully used to reach the best design for the interface (Developer, 2012).This was one of the most essential requirements which enabled the user to proactively work with the application in an unsupervised and uncontrolled environment, and in the absence of a trained professional.

Fitting the popular platform: There are many commercial platforms available, so we needed to consider which the most popular operating system (that was regularly found by people using smart phone devices) was.

User/password: Each user had to have a special record in the database identified by a unique user name and password. These records could be browsed and retrieved by the administrator of the online database host. All data had to be handled in accordance with research ethics and the Data Protection Act of 1998.

Real Time Scoring: A scheme that would score and record the dual aspects of food hedonic components "wanting" and 'liking" in free-living real time was needed. It had to be easy for the subjects to enter the "wanting" and "liking" events in a simple, fast and direct way. Scores and time of events had to be recorded once the individual pressed a particular and conspicuous button. These measures would also accurately replicate the standards and assessments that had been previously done.

Identify the events time and duration: We were looking not only for scores of "wanting" and "liking", but also for the timings and continuous patterns of these events, and for the duration of any intake events.

Auto synchronisation with the online database: All input would first have to be saved on the device's memory (in case of a disconnection from the internet or 3G network). Then, all data would be automatically sent via network to the online database to be sorted and saved. All data had to be retrieved and exported from the online database host, which was then exported into statistical software for further analysis.

Intake specification: It was important to specify and distinguish between different types of intake events such as food or drink.

Simplicity: In order to let the users navigate their way through the applications easily and quickly, there was a need to limit the application to one to three screens. Thus, the user interface was able to circumnavigate all aberrant situations that may arise when the user interacts with the application, and also had a simplistic touch to it, so that the participants could understand the workings of the system intuitively.

Sufficient functionality: The administrator had to be provided with a convenient and efficient manner of having the data obtained from the participants' interactions with the system, stored and collected. This would help professionals analyse the data more conveniently and better understand the implications of the measurements.

2.4 Design

A code-level application was designed. The architecture demonstrated the main components and relationships between these components (Figure 2.1). Based on previous requirements, we chose a mixed approach, using the two mainstream smartphone operating systems. First, IOS which is an operating systems developed by Apple Inc. and distributed exclusively for Apple hardware. Second, an Android which is an open-source operating system used for smartphones and tablet computers and is developed by Google. This mixed approach was highly beneficial because it allowed us to use the best features of both the Android and IOS operating systems. Moreover, Android and IOS smartphones (e.g. iPhone, Galaxy, Samsung, HTC, Nexus) have the lead over other phones (Fact and Figures 2014) (e.g. Windows and Blackberry). Although iPhone was the target platform for the initial development process, a similar approach was adopted for the Android platform, and the same approach could be applied for other platforms in the future (e.g. Windows Phone 7 and Blackberry).

This section explains the architecture which consists of four major component of the (Mind Eating) application: Wanting, Duration, Liking, Online Database. (See Figure 2.1.)

Wanting: This component is considered the first phase when the user experiences a wanting or a craving event. In this phase, the user will be guided to go through four steps:

- *"Wanting Time":* The user enters a wanting event and the time is recorded as the time of wanting.

- *"Wanting score"*: The user rates his perception of wanting by choosing a score between 0 and 10 - *"Food or Drink":* The user specifies if the wanted intake is food or drink. If the event is a meal, then the user should proceed with the Food button.

- *"Start intake":* The user needs to choose between ending this phase by pressing the "End" button (when wanting does not lead to intake), or press the "Start Intake" button (this is when food/drink will be consumed) and move to the next phase.

Duration: The application automatically calculates the intake event duration. The user is able to end the event and is sent to the next phase to express liking.

Liking: This component allows the users to express their liking (reward).

- *"Liking Time:* The user enters the liking event and the time is recorded as the time of liking.

- *"Liking score"*: The user enters his perception of liking by choosing a score between 0 and 10.

Online database host: Data sent by the application is stored in an online host.

Figure 2.1 illustrates the relationship between all major components.

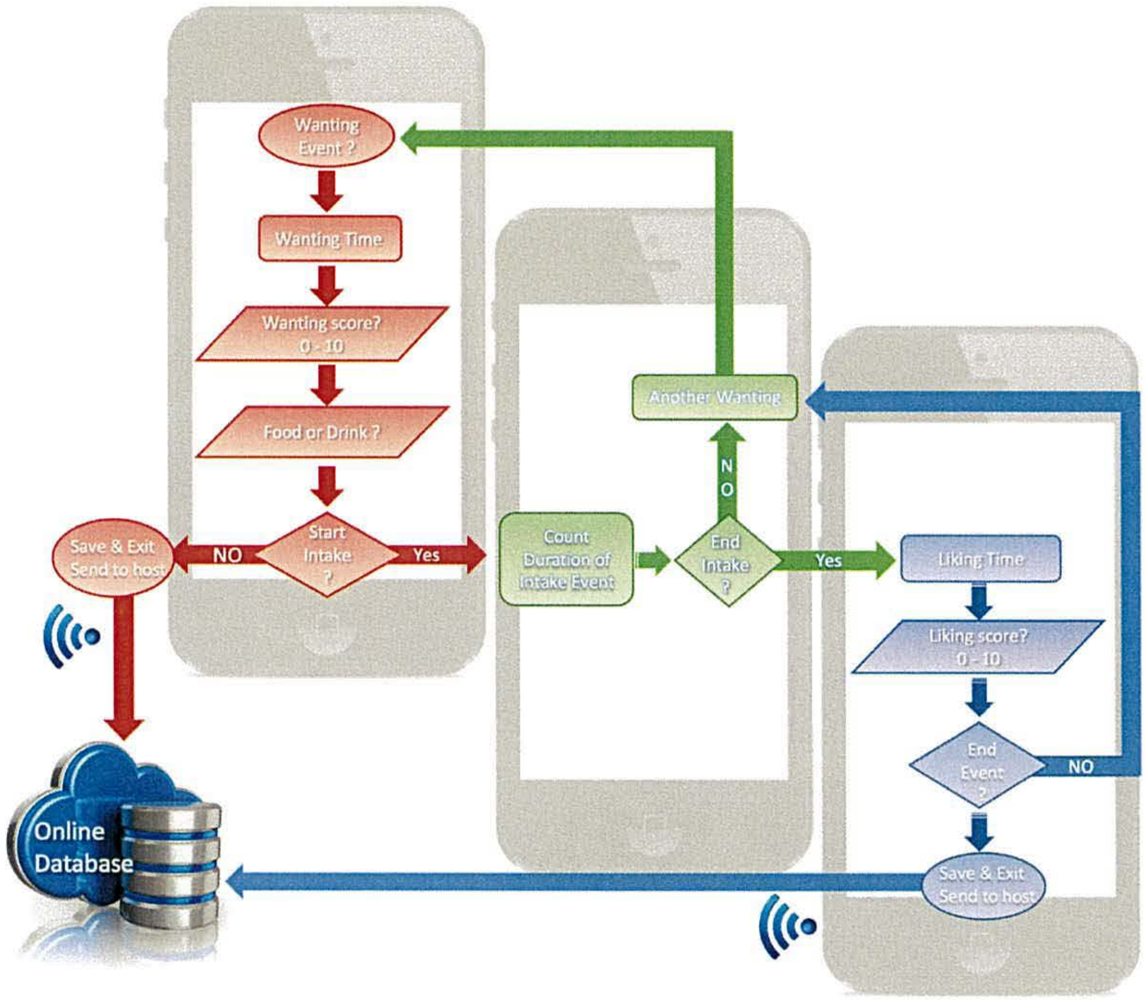

Figure 2.1. The relationship between all major components.

2.5 Mapping with Functionality

This section identifies how we implemented the components defined in the system architecture, as well as what technologies were used to satisfy the component responsibilities.

Database Part:

To provide (Mind Eating) online content through the Internet, the (Mind Eating) Database was established with a number of components. Figure 2.2 shows the mapping from our functionalities into the database architecture.

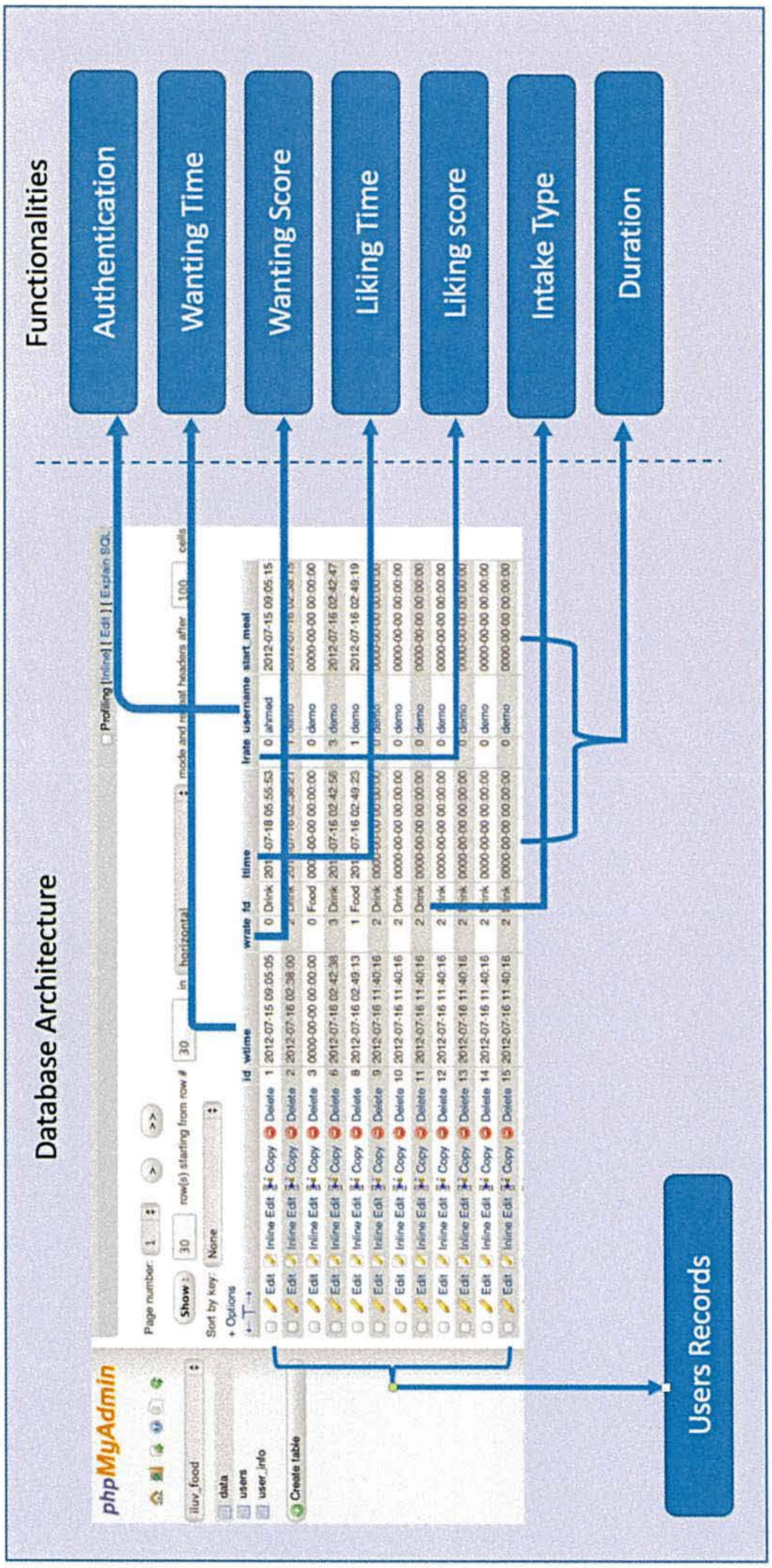

Figure 2.2. Mapping from functionalities to database architecture.

User records: Each user has a unique record that includes all data sent from his or her device via the (Mind Eating) application. Each record includes the following components:

- *Authentication:* Each user owns a unique username which works as a primary key in the database. This username is provided by the researcher at the beginning of the research or trial, after which the user does not need to log in every time the application is used. For subsequent uses, the application opens directly in the "Wanting" phase. Data protection procedures were followed throughout the research process to ensure the participant's safety and anonymity was protected, and all personal information was handled according to the data protection legislation.

- *"Wanting Time":* The time of a single wanting event.

- *"Wanting score"*: The score of a single wanting event.

- *"Intake Type":* The type of event; wether it is food or drink.

- *"Liking Time":* The time of a single liking event.

- *"Liking score"*: The score of a single liking event.

- *"Duration":* Duration of a successful wanting (intake event) calculated by subtracting the two components as follows:

- "Start Meal" - "Liking Time". This operation is automatically done and stored by the server once data is received.

User Part:

Figure 2.3 displays a basic sketch of the (Mind Eating) user application and its mapping from functionalities. By using the Graphical user interface (GUI) of the application, the user has the following capabilities

- *Authentication:* The user will use this authentication only once at the beginning of the trial as this login will be a unique ID for the user. The user will not need to enter this login again during the trial.

- *"Wanting Time":* once the user presses this button, the wanting event and time will be recorded as the time of wanting.

- *"Wanting score"*: the user must scroll down a component called the "Picker", which displays a set of scores from 0 to 10, to explain how much craving or wanting is experienced.

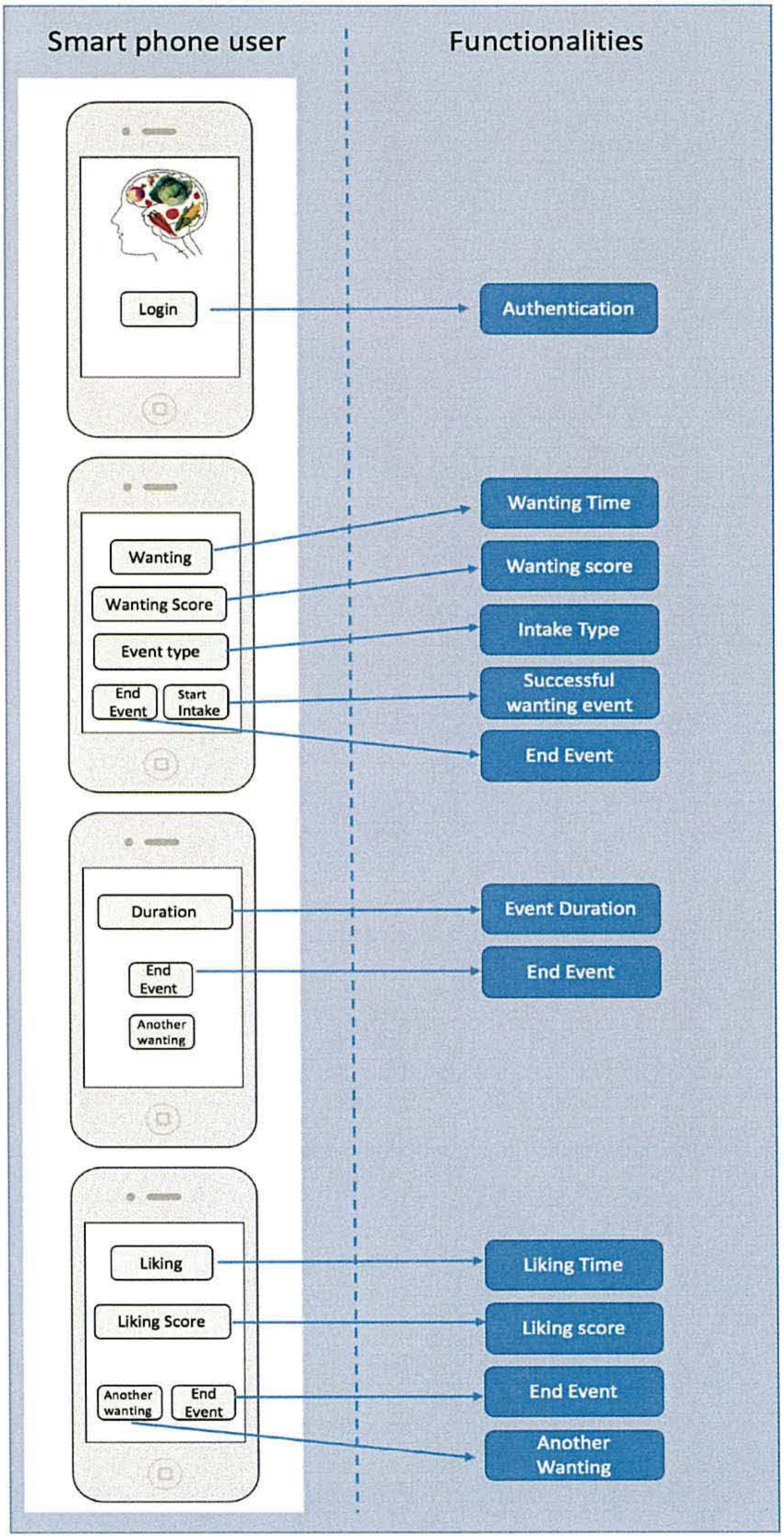

Figure 2.3. Mapping from functionalities to user application.

- *"Intake Type":* the user should choose whether food or drink is wanted. If the event is a meal, then the user is supposed to choose the Food button as wanting a meal is considered to be food.

- *"Start Meal":* the user is supposed to choose between ending this phase by pressing the "End" button (when wanting does not lead to food/drink consumption), or pressing the "Start Intake" button (when food/drink will be consumed) and move to the next phase.

- *"End Event":* by using this functionality, the user will be able to exist the application. Data will be automatically stored on the device and will then be sent to the database on the online host.

- *"Duration":* A visible timer of the intake duration (successful wanting event) will keep counting until the user chooses to "End Event" or chooses "Another Wanting" on the same screen. If "another wanting" has been chosen, the user will be sent to the first screen of wanting.

- *"Liking Time":* In order to express the liking and the enjoyment of the food/drink after intake, the user should press the liking button and the timing of the liking will be stored as the ending of the event.

- *"Liking score"*: the user must scroll down a component called the "Picker", which displays a set of scores from 0 to 10, to explain how much liking or enjoyment they experienced.

2.6 Implementation

A pilot application has been developed based on the features mentioned in the design section. Galaxy and iPhone devices were selected as target smartphone platforms. The following section will include the description of the implementation of both Android and IOS platforms inanition to the database host (see Figure 2.4).

Figure 2.4. Display the plat forms of Mind Eating smart phone application development. The application is legally authorised in apple store market.

The main design goal primarily embodies a simplified UI enabling the user to interact with the system effortlessly. The elements have been summarised in Figure 2.5, which shows the main components and elements of the Mind Eating application UI.

User Part:

IOS: To implement novel features, the iPhone development platform provides a well-designed Application Interface (APIs). The iPhone application was implemented with the IOS 4 Software Development Kit (SDK) Xcode v.4. An IOS Apple developer program membership was registered and a development provisioning profile was created in order to run, test and download our developed application.

We used Xcode v.4 as IDE, which is an integrated development environment that manages our application resources and lets us edit the code that ties different pieces together. Objective-C and Coca were used as programming languages of Apple platforms. The developed application was tested on the iPhone 3GS, iPhone 4, iPod Touch (second generation), and iPad to check compatibility issues and software bugs.

Android: In order to convert the (Mind Eating) application design into reality, Eclipse v 4.4.2, which is an integrated development environment (IDE) workspace, was used to develop and create the Android version of (Mind Eating) application. Eclipse includes a base workspace and an extensible plug-in system for customising the environment to build the applications that take full advantage of the device's hardware, connected accessory devices, the Internet, software features, and more.

The first version of our Mind Eating application was focusing on implementing the proposed features and functionalities described in the design section and as illustrated in Figure 2. Implementation of the user interface considered the reliability and simplicity of using all the components (see Figure 2.5).

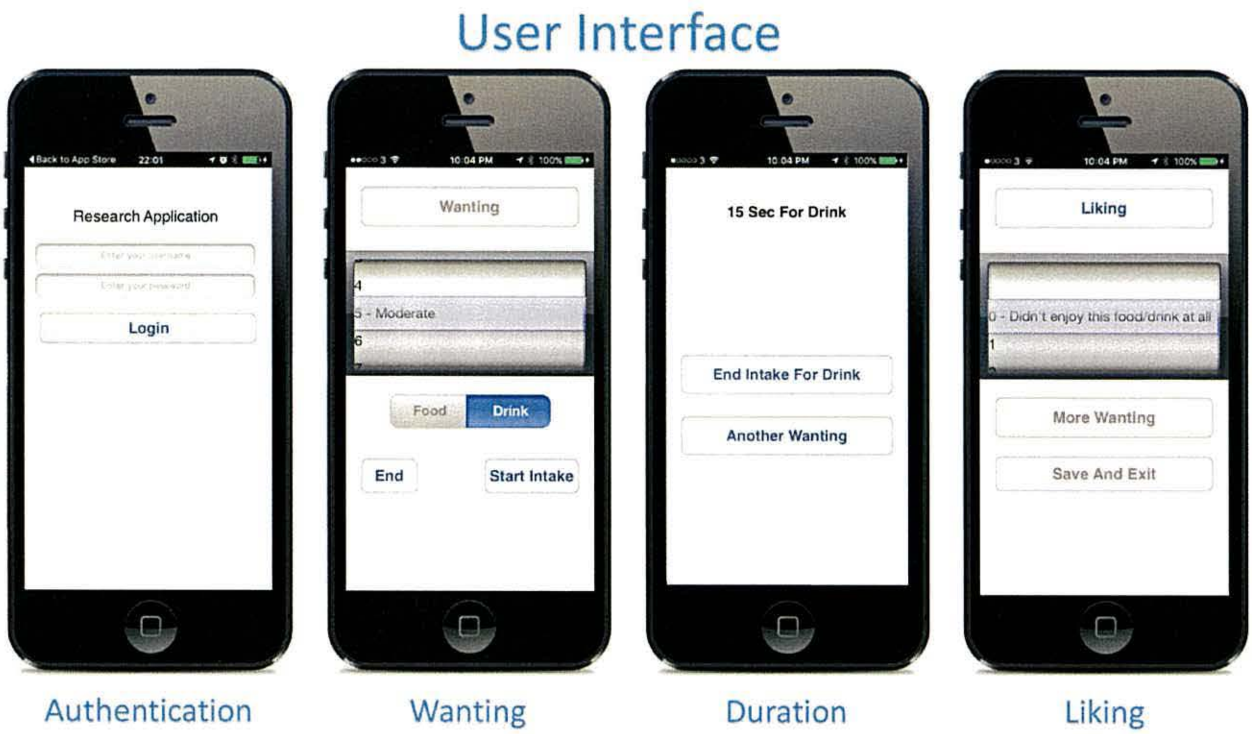

Figure 2.5. User graphical interface of iPhone.

1- Authentication screen where user enters the username and password. 2- Wanting screen where user enters the wanting and successful wanting events. 3- Duration screen where duration of the events is counted and displayed. 4- Liking screen where user enters the liking scores and terminates the event or chooses another wanting.

The application includes the following components which all work together in order to measure the hedonic response of the user in real life and real time:

- *"Wanting" Button*: once the user presses this button, the wanting event and the time will be recorded as the time of wanting.

- *"Wanting score" Picker:* user can scroll down a component called the "Picker" which displays a set of scores from 0 to 10 to explain how much craving or wanting they are experiencing.

- *"Food or Drink" check box:* by pressing this button, the users should choose whether they want food or drink. If the event is a meal, then they need to choose the Food button as wanting a meal is considered to be food.

- *"Start intake" button:* the user chooses between ending this event by pressing the "End" button (when they want food/drink but are not going to eat/drink) or pressing the "Start Intake" button (when food/drink will be consumed) and move to the next screen.

- *"Duration" timing component:* Auto timing of duration is displayed in this field showing a timer of the event/meal duration. This timer can work in the background of the IOS while the device is in sleep mode. User can enter the application any time to either "End" or add "Another wanting".

- *"Liking" Button*: once the user presses this button, the liking event and the time will be recorded as the time of liking.

- *"Liking score" Picker:* the user scrolls down a component called the "Picker" which displays a set of scores from 0 to 10 to explain how much liking or enjoyment they experienced.

All user-entered data are initially stored on the device's application memory and sent directly to the server when connectivity with the network (e.g. Wi-Fi or 3G) is restored. This is a very important step as some users may not be connected whilst using the application. In this case, all data will be stored on the device and will be sent once the network is available.

Database Part:

The cloud infrastructure supporting the Mind Eating application is a pool of standard Linux-based servers. The relational database management system software, MySQL (Oracle Corporation, Redwood Shores, California, United States), was used to store, query and access data items contained within the relational database using structured query language (SQL).

2.7 Pilot Study and Evaluation

Post the implementation level our application "Mind Eating" was ready to be used for pre-testing and investigate its capability and reliability for future research purpose. Therefore, a pilot study was conducted targeting the following aims:

Aims of the pilot study

1. Pre-test the functionality of the operating system-level software.
2. Testing compilers and capability of the data transformation between the user's device end the data base.
3. Testing the connectivity and the functionality of the application in all networks situation.
4. encompasses user's interaction experience. Using data from analytics, user feedback and technological breakthroughs to constantly reassess and improve experience.

Methodology

Ethical Approval

The experimental protocol was approved by the ethics board of the School of Sport, Health and Exercise Sciences (SSHES), Bangor University. The participants of the study were all provided written informed consent after receiving an explanation of the procedures and risks involved, both verbally and in the form of distributed participant information sheets.

Subjects and Design

Twenty two (Lean n=12 and overweight/obese n=10) were randomly assigned to either IOS or Android platform based on what device they already owned,(Female n=17, Male n=5). Recruiting were by advertising campaign including posters, leaflets, emails, word of mouth in the university and surrounding areas. As an incentive to take part in the study, participants were provided information on their body composition and on request, advice on exercise and eating behaviour change.

A preliminary screening process was utilized to ensure that participants were; (a) aged between 18 and 40; (b) free from cardiovascular, pulmonary, metabolic or musculoskeletal disease risk or injury; (c) classified either as lean (BMI: 18.5-25 kg/m^2) or overweight/obese (BMI: >25 kg/m^2); and (e) iPhone or Android smart phone users. The eligibility of potential participants was assessed by phone prior to arranging an initial appointment. Participants with conditions known to influence appetite including diabetes, cancer, depression and eating disorders were excluded, as were participants on medications known to influence appetite such as diabetic medications, antidepressants, and corticosteroids. Those who could not access their phones while at work were also excluded.

Measures

Anthropometry composition.

Participants dressed in light-weight clothing without footwear and emptied their pockets. Measurements were then recorded for height (to the nearest 0.1 cm), body mass (to the nearest 0.1 kg), and body composition with a stadiometer (Bodycare Products, Southam, United Kingdom) a balance (Seca, Hamburg, Germany), and a bio-electrical impedance analyser (Inbody 230, Biospace Ltd, California, USA), respectively. Body composition including fat mass, and body fat percentage was measured using a bioimpedance analysis (BIA) (Inbody 230, biospace co., Ltd, Korea).

A wall-mounted stadiometer was used to measure height (Bodycare Products, Southam, United Kingdom). Weight was measured using a calibrated balance scale (Seca, Hamburg, Germany). Participants were asked to wear light clothes and to remove shoes and metal objects.

"Mind Eating" smart phone application

"Mind Eating" smart phone application was used in this study to be investigated and piloting for pre-testing the functionality and capability. The development and implementation of this application was explained previously in detail in this chapter. participant was guided to download and use the application. The application available for download from apple store and google store.

Procedure

The participants attended the laboratory for installing the "Mind Eating" application and obtained the consents forms. After that participants were asked to download the Mind Eating smart phone application from the Apple Store for (IOS) platform users, or to receive it as a file by email or download from google store for Androids platform users. Participants were given authorisation access to the Mind Eating application. The application was comprehensively explained and introduced for the participants. In addition, a detailed manual for using the application was given to all participants (see Appendix A). Participants were asked to record food 'wanting' on a scale of 0 (*not at all*) to 10 (*very strongly*) each time food 'wanting' was perceived, and to record 'liking' of food immediately after each eating episode using the same scale, continuously for 14 days. Data were collected via an online database host.

Results

The (Mind Eating) applications was implemented and evaluated to measure the "wanting" and "liking" components of eating behaviour. To test and evaluate the capability and reality of the (Mind Eating) application to measure "wanting" and "liking" components, a pilot study was conducted with Twenty two students from Bangor University. They were randomly assigned to either IOS or Android platform based on what device they already owned. The implementation and evaluation process loop of the application took twelve months of continuous execution, testing and correction procedure. This process revealed four improved versions of the application. The participants entered the pilot study sequentially. Each participant was introduced to the application with full explanation of all the features and the procedure of using the application. Participants were asked to use the application for continuous 4 weeks. In the initial stage of the pilot study, a number of technical issues considering design and system were raised and solved directly. Moreover, a dropout was noticed after the first two weeks of the experiment and the quality of the data consequently dropped after this period. Therefore, after analysing the initially obtained data and comparing both the complete and incomplete assessments, we decided that the best length of application use should be kept to two weeks. This was expected to contribute to the consistency of data collection. Another key consideration was related to the network efficiency. The approach was evaluated and developed for Wi-Fi or 3G network, however, if this network disappeared, any data obtain from the application would be lost. To solve this problem, we developed a local storage property in the application itself to act as a local memory for the inserted data when the application is offline.

The accuracy of the classification process was critically important to the overall performance of the Mind Eating application. Performance of the Mind Eating application was obtained and profiled from the pilot study users and analysed in-depth for each participant. In the preliminary experiment, we observed that the scores produced by the Mind Eating application corresponded with the behavioural patterns of the pilot study users. Table 1.1 presents a sample of data and charts obtained for one particular user. It illustrates data of a particular user for both drink and food events gathered over a period of 14 days. The count column shows the frequency of events, that is the number of drink/food events. Scores for "wanting"(W-score) and "liking" (L-score) events represent the users' rating of their wanting/liking events, calculated in two different ways: (1) accumulation of all scores for that day as shown in the table with Sum of W-score or Sum of L-score; (2) average scores of that day . Moreover, the duration of intake and its average was calculated as well.

Frequency of the events is shown in the (count) column. Scores for "wanting" and "liking" events were calculated in an accumulation way (Sum of W-score / Sum of L-score) or an average way (Average of W-score / Average of L-liking score). Duration and average duration of event intake is shown for each day.

Figure 2.6 displays all successful W-scores and L-scores for both food and drink; Figure 2.7 displays all successful W-scores and L-scores for food only; and Figure 2.8 displays all wanting events and their frequency. Figure 2.9 displays chart analysis of on data.

Table 2.1. Data of a particular user for both food and drink events over 14 days.

Row Labels	Column Labels: Count		Sum of W-score		Average of W-score		Average of L-score		Sum of L-score2	
	Drink	Food	Drink	Food	Drink	Food	Drink	Food	Drink	Food
15/03/2014	2	5	15	33	7.50	6.60	6.50	7.40	13	37
16/03/2014	2	4	15	28	7.50	7.00	5.00	5.00	10	20
17/03/2014	1	3	6	17	6.00	5.67	7.00	6.00	7	18
18/03/2014	0	6	0	37	0.00	6.17	0.00	5.83	0	35
19/03/2014	5	6	34	33	6.80	5.50	7.80	5.83	39	35
20/03/2014	1	5	8	36	8.00	7.20	9.00	6.00	9	30
21/03/2014	1	3	8	22	8.00	7.33	4.00	3.00	4	9
22/03/2014	2	4	12	26	6.00	6.50	7.00	6.75	14	27
23/03/2014	0	5	0	31	0.00	6.20	0.00	5.40	0	27
24/03/2014	2	5	12	28	6.00	5.60	5.00	5.80	10	29
25/03/2014	1	4	9	27	9.00	6.75	9.00	7.00	9	28
26/03/2014	1	5	6	32	6.00	6.40	3.00	8.00	3	40
27/03/2014	1	3	3	22	3.00	7.33	6.00	5.67	6	17
28/03/2014	1	6	6	40	6.00	6.67	7.00	7.33	7	44
Grand Total	**20**	**64**	**134**	**412**	**6.70**	**6.44**	**6.55**	**6.19**	**131**	**396**

Row Labels	Sum of Duration		Average of Duration		Total Count	Total Sum of W-score	Total Average of W-score	Total Average of L-score	Total Sum of L-score2	Total Sum of Duration	Total Average of Duration
	Drink	Food	Drink	Food							
15/03/2014	0:44:39	1:01:31	0:22:19	0:12:18	7	48	6.86	7.14	50	1:46:10	0:15:10
16/03/2014	1:26:12	2:58:55	0:43:06	0:44:44	6	43	7.17	5.00	30	4:25:07	0:44:11
17/03/2014	0:40:39	0:50:45	0:40:39	0:16:55	4	23	5.75	6.25	25	1:31:24	0:22:51
18/03/2014	0:00:00	1:26:25	0:00:00	0:14:24	6	37	6.17	5.83	35	1:26:25	0:14:24
19/03/2014	2:05:41	1:28:50	0:25:08	0:14:48	11	67	6.09	6.73	74	3:34:31	0:19:30
20/03/2014	0:11:47	1:53:52	0:11:47	0:22:46	6	44	7.33	6.50	39	2:05:39	0:20:57
21/03/2014	0:14:02	1:45:39	0:14:02	0:35:13	4	30	7.50	3.25	13	1:59:41	0:29:55
22/03/2014	0:56:09	1:44:37	0:28:05	0:26:09	6	38	6.33	6.83	41	2:40:46	0:26:48
23/03/2014	0:00:00	2:11:49	0:00:00	0:26:22	5	31	6.20	5.40	27	2:11:49	0:26:22
24/03/2014	0:18:28	3:00:43	0:09:14	0:36:09	7	40	5.71	5.57	39	3:19:11	0:28:27
25/03/2014	0:13:33	1:05:40	0:13:33	0:16:25	5	36	7.20	7.40	37	1:19:13	0:15:51
26/03/2014	0:08:28	1:27:01	0:08:28	0:17:24	6	38	6.33	7.17	43	1:35:29	0:15:55
27/03/2014	0:29:24	1:37:13	0:29:24	0:32:24	4	25	6.25	5.75	23	2:06:37	0:31:39
28/03/2014	0:39:58	3:32:55	0:39:58	0:35:29	7	46	6.57	7.29	51	4:12:53	0:36:08
Grand Total	**8:09:00**	**26:05:55**	**0:24:27**	**0:24:28**	**84**	**546**	**6.50**	**6.27**	**527**	**34:14:55**	**0:24:28**

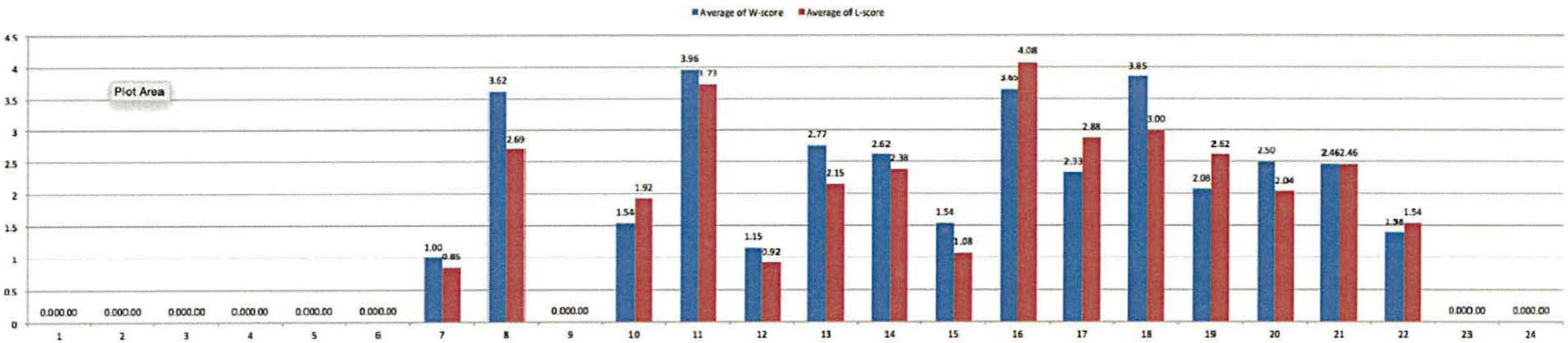

Figure 2.6. All successful W-scores and L-scores for both food and drink.

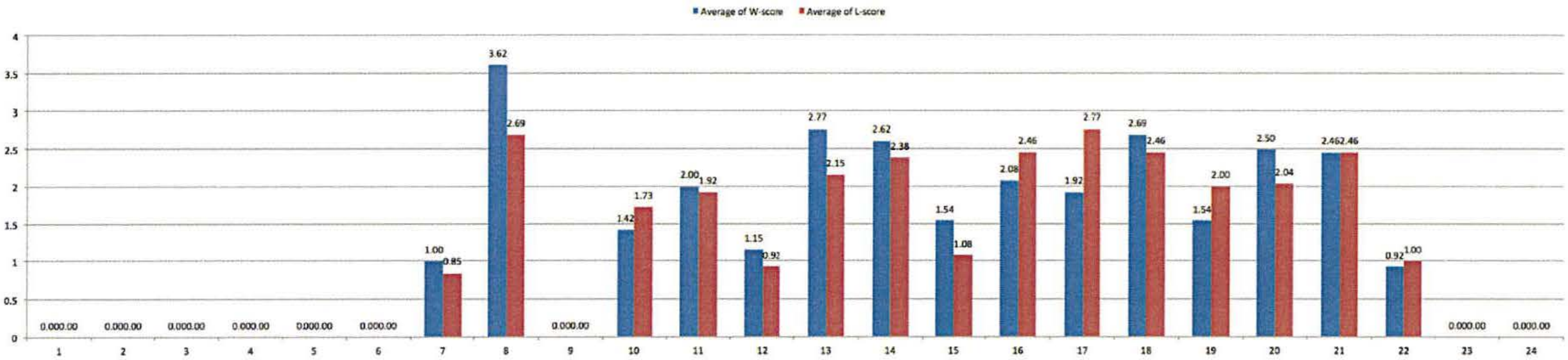

Figure 2.7. All successful W-scores and L-scores for food only.

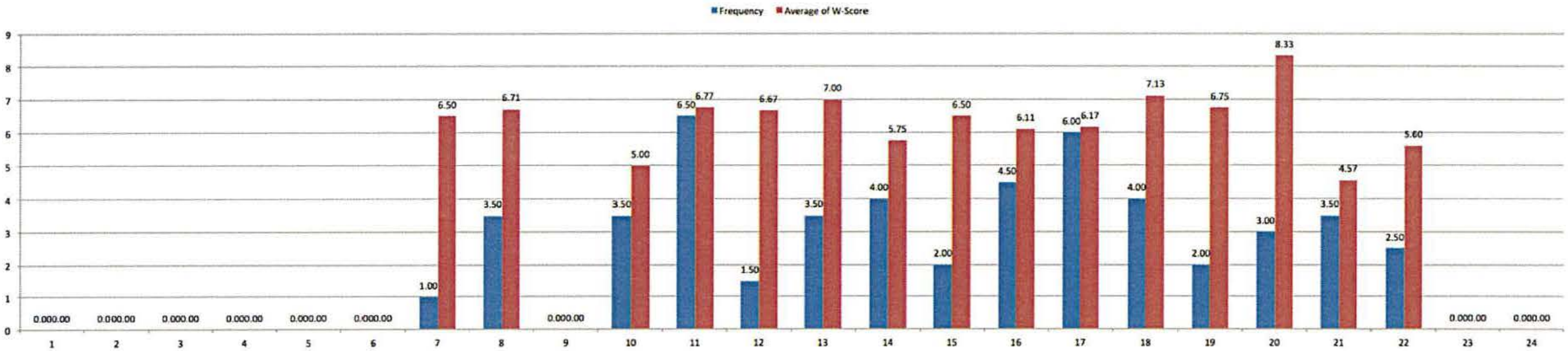

Figure 2.8. All wanting events and the frequency of events.

Figure 2.9. Excel Macros for chart analysis

2.8 Related Work and Discussion

The non-homeostatic or hedonic mechanisms (reward) are at the centre of current studies on energy balance and overconsumption that target prevention of obesity (Berthoud, Lenard, & Shin, 2011). In this chapter, we have described the process of developing a smartphone application (Mind Eating) for two different platforms (iPhone/Android), which is aimed at assessing the hedonic components "wanting" and "liking".

Mobile phones are ubiquitous and are considered the main mode of communication for most people. Between 2005 and 2015, the number of mobile phone subscriptions increased from 2 billion to more than 7 billion, as reported by The International Telecommunication Union (May 2014) .This is equivalent to 95.5 percent of the world population. Advancements in mobile phone technology have made it a desirable method for health promotion and disease prevention (Cole-Lewis & Kershaw, 2010), including the prevention of obesity.

Research suggests that there are health benefits of using technology, such as the Internet (Azar et al., 2013; Turner-McGrievy & Tate, 2011) and mobile technology (Riley et al., 2011; Stephens & Allen, 2013). Novel digital technology can deliver health behaviour interventions targeting lifestyle change and weight management, however, their effectiveness has not been determined yet (Free et al., 2014). Nonetheless, the proliferation of software applications (apps) for smartphone technology has produced a new and promising approach to behaviour measurements and lifestyle interventions (Stephens & Allen, 2013). Moreover, these technologies can help increase the number of people that can participate in measurements and interventions, which can be delivered at an affordable price.

To address the knowledge gap in our understanding of people's eating behaviours, our smartphone application (Mind Eating) was developed to record the continuous patterns of "wanting" and "liking" of food in real life situations. Unlike the highly controlled laboratory and questionnaire-based assessments which had the disadvantage of creating specific environmental conditions far removed from real life scenarios (Blundell et al

2005, Dykes et al 2004), the development of the Mind Eating application enabled the direct targeting of explicit hedonic components and of the homeostatic (hunger, appetite) aspects. "Wanting" here refers to craving and reward expectations, and also to hedonic components. "Liking" includes palatability and satisfaction (reward). The application also scores the intensity of individual's "wanting" and "liking" and automatically records the timing of these events, also measuring the frequency of eating events and their duration.

Laboratory-based studies provide a controlled environment in which certain aspects of eating behaviour and appetite can be isolated and studied without external influences. However, they are often removed from reality and do not collect data in real situations (Gibbons et al., 2014). Our study aimed to explain aspects of eating behaviour and eating patterns that could be best studied on real people in their natural environment. Previously, army cadets have been studied in a free-living but controlled environment (Widdowson, Edholm, & McCance, 1954). This study did not employ a controlled environment and attempted to capture people's real life behaviours. Free-living studies have been criticized for their lack of validity and reliability, however, they have also been acknowledged as necessary methods for measuring eating behaviours in the free-living environment, and progress has recently been made to increase their accuracy (Gibbons et al., 2014). Previously conducted free-living studies had different methodological limitations and merits. They ranged from food acquisition studies to post-intake studies depending on recalls of a person's eating behaviour (Wansink, 2009). The Mind Eating application is the first step to record eating behaviour in real time and does not depend on recall or predictions.

In order to measure the "liking" component, some previous studies have measured the hedonic components of reward by concentrating on preferences and palatability (Finlayson et al., 2007) . Feest (2005) emphasized that operational definitions should not be confused for facts. Using the Leeds Food Preference Questionnaire, Dalton et al. (2013) found that the differences in wanting and liking of high fat, sweet foods were apparent in a subtype of obese participants who were identified as binge eaters using the Binge Eating Scale. In another study, using laboratory based computer tests to measure wanting and liking of high fat foods, wanting and liking were found to correlate with energy intake but not BMI (French et al., 2014). Measures of wanting and liking in those studies differ from those used in our study in that the relative wanting was measured by reaction time in a forced image choice computer test, and liking was measured in a theoretical way using images rather than assessing actual post-consumption pleasure, as our Mind Eating application does.

2.9 Study Limitations

As with all studies that rely on self-reporting, our study could be subjected to underreporting, which presents a methodological problem (Murakami & Livingstone, 2014). Participants have to enter their "wanting" and "liking" using a smartphone application, so data collection depends on their accurate input. Only the "wanting" and "eating" they are consciously aware of is recorded in their answers. Gibbons et al. (2014) asserted that people are often not able to accurately assess their implicit "wanting" for food, and this component is to some degree included in responses reflecting motivations for food, which should be as spontaneous as possible to capture the core process of "wanting". Furthermore, the scoring used in the Mind Eating application is subjective and measured without external calibration. Participants enter their scores that relate to unspecified food and drink intake, which makes the scores general and does not allow for comparisons with other studies that compared one food to another or specific foods to non-food items.

Due to time and financial limitations, we were not able to develop and test an application that would support all mobile platforms. Our application was tested only on IOS and Android operating systems, but theoretically, it could support different smart device platforms. As for the practical implications of our study, there is limited evidence that mobile phone technology can be effectively used for behaviour change and disease management (Free et al., 2013).

2.10 Conclusion and Future Work

In this chapter, we have described the development of the (Mind Eating) iPhone and Android application based on required functionality specifications. We created the specifications of the (MindEating) application based on several important requirements, and then implemented an iPhone application and a corresponding online database host considering the application's performance. The iPhone and Android versions of the Mind Eating application are now available on Apple store (smartphone app market).

In the future, we will continue to work with the Mind Eating Application to conduct some experiments related to hedonic components and reward assessments. Since the time of events and the frequency are assessed and identified by this application, eating behaviour patterns could be investigated in depth. Using this application, we will be able to analyse the continuous patterns of "wanting" and "liking" of food in real life situations and compare obese individuals with lean matched controls (as we will see in chapter 3) to gain a deeper insight into the psychological drivers of obesity. It was hypothesised that obese people would exhibit different food "wanting", "liking" and eating patterns compared to lean controls.

Mind Eating application could also be developed to involve a proper intervention that depended on the hedonic assessment obtained from the application.

CHAPTER 3

3. Study 2: Free-Living Pattern of 'Wanting' and 'Liking' of Food in Lean and Obese Individuals Assessed with Novel Smartphone Application (Mind Eating)

3.1 Introduction

As obesity becomes a worldwide epidemic, researchers are debating the genetic, physiological and psychological causes of individuals gaining weight. The primary concept is that overconsumption leads to a positive energy balance in the body (Westerterp & Speakman, 2008; Swinburn et al., 2009). However, it is unknown whether the regulation of appetite in overweight and obese subjects is dominated by defects in homeostatic or hedonic systems of appetite control (Blundell & Finlayson, 2004).

Some studies have criticised this distinction of homeostatic from hedonic responses for oversimplifying the interdependence of physiological, cognitive, and behavioural processes (Berthoud, Zheng, Corkern, & Stoyanova, 2010; Mela, 2006; Saper, Chou, & Elmquist, 2002). Nonetheless, many researches consider that hedonic responses and the pleasure of eating are the primary drivers of appetite and food consumption in overweight subjects (Cox et al., 1998; de Graaf et al., 2005; Nasser, 2001); that is, that eating behaviour is driven primarily by pleasure-seeking and not by homeostatic regulation (Lowe & Butryn, 2007). In particular, it is thought that the obesogenic environment of the modern world exposes us continuously to food stimuli to the extent that hedonic reward-driven behaviours play a more significant role in food intake than do homeostatic ones. Therefore, this simple classification will be maintained.

Hedonic rewards are either consummatory, that is, 'liking' (e.g., satisfaction, palatability), or anticipatory, that is, 'wanting' (craving). To date, consummatory reward has been correlated to BMI only in individuals with low self-esteem (Lawrence et al., 2012). However, a lower activation in the reward areas of the brain during eating and a lower density of dopamine D2 receptors (Wang et al., 2001; Volkow et al., 2008) imply that overweight and obese subjects responded to anticipatory rewards more than lean ones did (Stice et al., 2009). Thus, Berridge (2009) theorised that obese individuals experience a higher incentive salience for particular foods, and anticipate a greater reward from eating food ('wanting') than is realised in the pleasure of its consumption ('liking'). If this is true, the regulation of a neutral energy balance may depend not only upon the frequencies and patterns of 'wanting' events, but also on how often hedonic cues and thoughts about food are resisted and do not lead to meal intake.

In addition to these anticipated and consummatory rewards of food, eating behaviour is influenced by an individual's attitudes towards the costs and benefits of food. These attitudes are either explicit (i.e., deliberate and conscious) or implicit (i.e., spontaneous and subconscious) (Craeynest et al., 2005). Although explicit attitudes towards food did not differ significantly between lean and overweight groups, Sartor et al. (2011) developed a computer exercise that showed overweight/obese subjects had higher implicit attitudes (i.e., a subconscious preference) for sweet foods than did lean individuals.

To address the huge gap in our understanding of people's eating behaviour, we have recently developed a smart phone application (proposed in Chapter 2) to analyse and record the continuous patterns of 'liking' and 'wanting' in lean and overweight and obese individuals. This app overcomes two limitations of previous research on eating behaviour. Firstly, unlike questionnaires, the app captures data for 'liking' and 'wanting' events on a continuous time scale. Secondly, these patterns of behaviour are studied in real-life contexts outside of the laboratory (Dykes et al., 2004; Blundell et al., 2005). The app is used to score 'liking' and 'wanting' events as they occur and automatically records their scores, timings, durations, and frequencies. Thus, by measuring the rhythms and intensities of the hedonic drivers of food intake, we predict that differences in the 'liking' and 'wanting' events of lean and overweight/obese individuals will help us understand the mechanisms causing obesity and reveal insights about how to treat it.

3.2 Aims:

- Analyse and record the "Wanting" and "Liking" in real life situation (14 days).
- Investigate the differences between individuals (lean, overweight and obese) in their eating behaviour and hedonic components.
- Investigate the pattern of the individuals eating behavioural in term of time pattern.
- Testing the validity of the the phone application "Mind Eating".

3.2 Hypotheses

We hypothesized that participants with high body fat would display reduced consummatory reward perception (*liking* ratings) compared with the low body fat group in accordance with the reward deficiency theory.

Furthermore, we expected that the high body fat group would reveal high associations between their wanting recordings and craving dimensions due to the hypothesis that obese individuals would be more driven by hedonic than cognitive wanting and physiological state.

3.3 Methods

Ethical Approval

The study design was approved by the School of Sport, Health and Exercise Sciences, Bangor University ethics committee. Moreover, the study and the investigators were approved by the Ethical committee of Betsi Cadwaladr University Health Board (BCUHB). All participants were given an information sheet explaining all procedures of the tests involved in the experiment. As well as this, once the procedures had been explained verbally, all participants provided written informed consent (See Appendix 1 and 5).

Participants and Study Design

Participants were Bangor University staff, students and patients attending a local GP practice, and Betsi Cadwaladr University Health Board (BCUHB) staff and patients, aged 18–65 years, who responded to email, poster or letter advertisements about the study. Smartphone users in all weight categories were invited to apply. The eligibility of potential participants was assessed by phone prior to arranging an initial appointment. Participants with conditions known to influence appetite including diabetes, cancer, depression and eating disorders were excluded, as were participants on medications known to influence appetite such as diabetic medications, antidepressants, and corticosteroids. Those who could not access their phones while at work were also excluded.

Measurements, Materials, and Apparatus

Overview of implicit association task (IAT). In the present study, the IAT was conducted to measure the participants' implicit attitudes towards healthy and unhealthy food. The following explanation focuses on key aspects of this task (for further details, see Greenwald, McGhee, & Schwartz, ***1998***). The IAT is one of the more preferred methods for assessing implicit attitudes (Greenwald, Mc Ghee, & Schwartz, 1998), as the main concept of IAT tasks is to infer implicit attitudes from reaction time performance on computer sorting tasks. Individuals are directed to sort stimuli belonging to one of four categories. Two of them are target categories (e.g., healthy and unhealthy) and two are attribute categories (e.g., pleasant and unpleasant nouns). To carry out the sorting process, one of two response keys should be pressed as accurately and as fast as possible. Each response key represents one attribute and one target. The task is based on the assumption that response time is shorter when the same response is used for an attribute and a target category that are associated in memory (e.g., healthy and pleasant vs. unhealthy and unpleasant) than when the same response is used for unrelated categories (e.g., healthy and unpleasant vs. unhealthy and pleasant). This pattern enables the results to reflect automatic and implicit processing.

Stimuli and measuring IAT. Pictures of food stimuli were collected from public domain sources on the Internet. Eighteen coloured photos were classified into two categories: healthy (e.g., salad, fruit, and vegetables) and unhealthy (e.g., pizza, chips, and burgers) food. The pictures appeared in the centre of the computer screen, which also contained eight words with a positive (e.g., pleasant, lovely) and eight words with a negative connotation (e.g., nasty, bad). A score of the attitude result was given at the end of the test. Scores indicating a positive implicit attitude towards healthy food should be positive; scores indicating a positive implicit attitude towards unhealthy food should be negative; zero should indicate a neutral attitude towards healthy food.

The test was conducted using the IAT on a desktop computer in a computer room. The test was designed to measure implicit affective associations towards categories of food (e.g., healthy and unhealthy). To motivate the participants, the experimenter was present in the test room during the IAT. The IAT was explained to the participants as a categorisation task in which they had to decide as quickly as possible to which category each stimulus belongs. To avoid a biased approach to the task, participants were not given any further information about the purpose of the study (see Figures 3.1 and 3.2).

Figure 3.1. Examples of pictures used in the IAT.

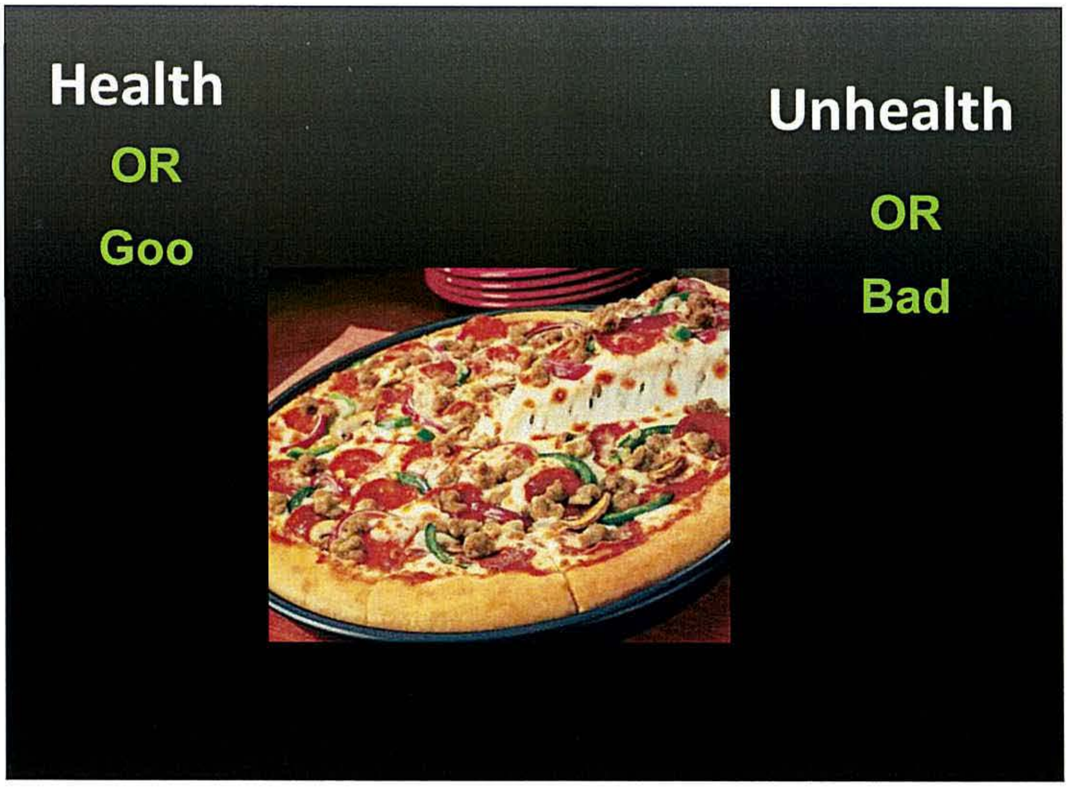

Figure 3.2. Snapshot of the IAT screen.

Explicit measuring. In order to establish explicit attitudes towards healthy eating, a questionnaire was carried out to collect the relevant data (adapted from Courneya & Bokick, 2000 by David Markland from School of Sport,Exercise and Health sciences in Bangor University). Eight elements were included in the questionnaire (e.g., enjoyable/not enjoyable, good/bad) to determine the main concept: "For me, eating healthy food is…" The scale ranged from 1 (*extremely*) over 4 *(neither)* to 7 (*extremely*). By summing up the total at the end, the total could range from 8 to 56. The higher the score the more positive was the participants' explicit attitude towards healthy food.

Food craving measuring. Craving was rated subjectively using a Food Cravings Questionnaire (FCQ). The FCQ is a validated questionnaire (Cepeda-Benito et al., 2001; Nijs et al., 2007) that differentiates between the physiological and psychological dimensions of eating behaviour and craving (Meule et al., 2012). Participants answered questions on the FCQ-Trait (FCQ-T) and the FCQ-State (FCQ-S), which are independent of or dependent on physiological or psychological states, respectively.

FCQ-T

Answers to the FCQ-T did not depend on the physiological or psychological state of the participants. Each statement was rated on a 6-point Likert-type scale from 1 (*never*) to 6 (*always*) according to how frequently it is true in general. The questionnaire assessed the following 9 dimensions of food craving:

1. Positive reinforcement – the anticipated positive emotional reward from eating.
2. Negative reinforcement – the anticipated relief from negative emotions after eating.
3. Feelings of hunger – general feelings of hunger or fullness.
4. Intentions to eat – making plans for eating food.
5. Cue dependent eating – the triggering of food cravings by environmental cues.
6. Negative effect – the effect of negative emotions on food craving or eating.
7. Preoccupation with food – thoughts or a preoccupation with food.
8. Lack of control – the loss of control over eating before and during eating.

9. Guilty feelings – guilt felt for food cravings and/or the lack of control over them.

FCQ-S

Answers to the FCQ-S did depend on the physiological or psychological state of the participants. Each statement was rated on a 5-point Likert-type scale from 1 (*strongly disagree*) to 6 (*strongly agree*) according to the extent it was true at the time of completing the questionnaire. The questionnaire assessed the following 5 dimensions of food craving (including sweet and savoury foods):

1. Positive reinforcement – the anticipated positive emotional reward from eating.
2. Negative reinforcement – the anticipated relief from negative emotions after eating.
3. Feelings of hunger – physiological feelings of hunger or fullness.
4. Lack of control – the loss of control over eating before and during eating.
5. Intense desire to eat – the intensity of the desire to eat a specific food.

Anthropometry composition. Participants dressed in light-weight clothing without footwear and emptied their pockets. Measurements were then recorded for height (to the nearest 0.1 cm), body mass (to the nearest 0.1 kg), and body composition with a stadiometer (Bodycare Products, Southam, United Kingdom) a balance (Seca, Hamburg, Germany), and a bio-electrical impedance analyser (Inbody 230, Biospace Ltd, California, USA), respectively. Body composition including fat mass, and body fat percentage was measured using a bioimpedance analysis (BIA) (Inbody 230, biospace co., Ltd, Korea).

A wall-mounted stadiometer was used to measure height (Bodycare Products, Southam, United Kingdom). Weight was measured using a calibrated balance scale (Seca, Hamburg, Germany). Participants were asked to wear light clothes and to remove shoes and metal objects.

Procedure.

The participants attended the laboratory for the baseline measurements and obtained the consents forms. Baseline characteristics were the following:

- Age, gender, weight, height, BMI, and % body fat (by BIA) at entry.
- Implicit association test (IAT) (Greenwald et al., 1998, modified).
- Explicit attitude questionnaire.
- Food cravings questionnaire (Crowley et al., 2012).

After that participants were asked to download the Mind Eating smart phone application from the Apple Store for (IOS) platform users, or to receive it as a file by email for Androids platform users (Figure 3). Participants were given authorisation access to the Mind Eating application. The application was comprehensively explained and introduced for the participants. In addition a detailed manual for using the application was given to all participants (see Appendix A). Participants were asked to record food 'wanting' on a scale of 0 (*not at all*) to 10 (*very strongly*) each time food 'wanting' was perceived, and to record 'liking' of food immediately after each eating episode using the same scale, continuously for 14 days. Data were collected via an online database host (see Figure 3.3).

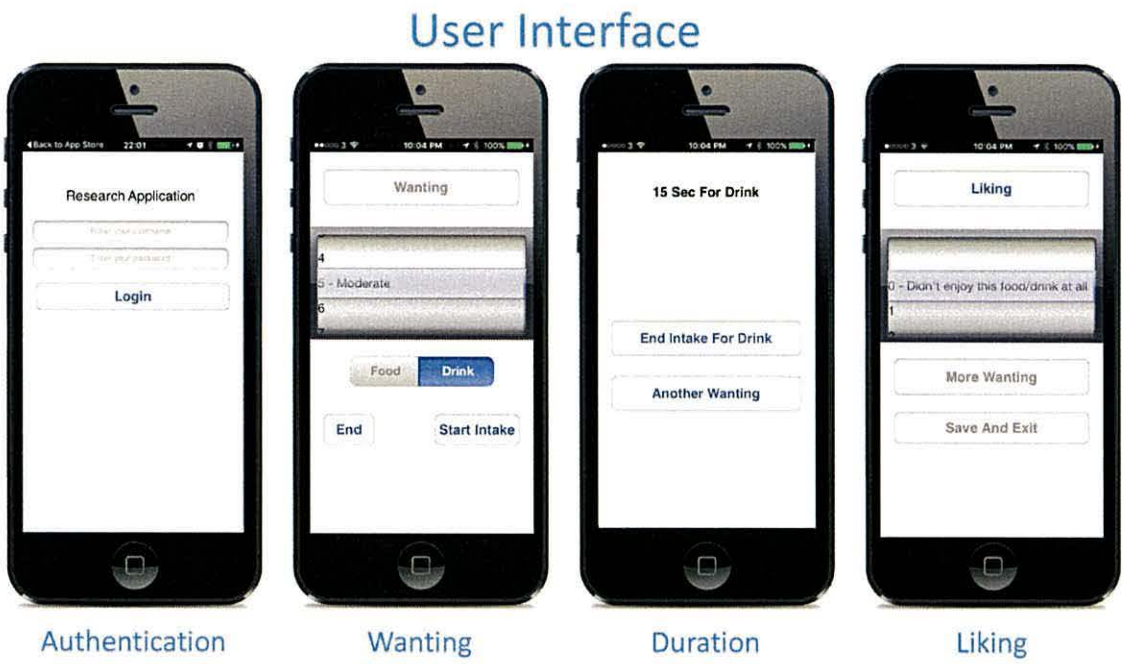

Figure 3.3. Mind Eating smartphone application user interface.

Data analysis.

Data in this study were analysed in two different stages. The first stage was an aggregate data analysis. The second was a time series analysis.

Aggregate data analysis. All statistical analyses were performed using IBM SPSS Statistics 20, after all relevant assumptions had been met and outliers removed. The analysis was conducted using a count regression model (Poisson model as the standard) for the frequency data, which consisted of discrete events. The negative binomial (NB) model was used to add an over-dispersion term and this resulted in significantly improved log-likelihood and information-criteria statistics compared to the Poisson model. Because all scores were rated on a commensurate scale, they could be subjected to a profile analysis, which is useful to examine whether the profiles of groups differ on a set of measures on the same scale (Tabachnick & Fidell, 2007). This method was used because the researcher was interested in the differences among groups, the difference between rating scores, and any interaction between group and rating scores. A profile analysis provides one method by which to examine these associations in a single analysis. Although the multivariate effects were of nominal interest, the researcher was primarily interested in comparing each rating type. Thus, the univariate contrasts were examined without undue regard for the multivariate findings, although the latter are reported for the sake of completeness. In order to examine a predictive model of reward from food, variables were entered in a series of steps hierarchically based on theoretical and logical merit, and a stepwise selection of variables was conducted. Bonferroni *post hoc* tests were conducted where appropriate. Pearson's correlations were used to analyse the relationships between variables. All data are reported as means ± SD. Statistical significance was set at $p < .05$.

Time series and pattern analysis. In order to extract meaningful statistics and other characteristics of the participants' eating behaviour data that have a natural temporal ordering, a time series analysis was conducted, which consists of successive measurements made over a time interval. Two types of software were developed by our colleagues Gabriele Papini and Francesco Startor from Personal Health–Philips Research Gabriele.

Matlab moving average software. This software calculates the moving average of the behaviour for all our participants over the 14 days of the experiment. An algorithm was designed to operate a customisable analysis of the data collected. This algorithm allowed us to split the data in two or more groups according to the fat percentage (fat %) or body mass index (BMI) of the participants. It was also possible to exclude from the analysis, participants with incomplete records, according to a given adherence level, [some kinds of] individuals, or a complete gender category. The algorithm also allowed us to change the window size of the moving average filter.

Participants' eating patterns were obtained from the 'wanting', 'liking', and unsuccessful 'wanting' scores (W, L, UW). The data recorded by the smart phone application was imported into Matlab (Mathworks, Massachusetts, Natick, 2013) and assigned to three vectors, one for each type of score (i.e., W, L, UW). Each day of a participant's ratings was characterised by these three vectors, in which each cell represented 1 min of the tested day. In cases there were no input scores rated by the participants, the 1-min cell values were set to zero. One group of standard day score vectors (SDSVs) was calculated for each participant and then for each body fat percentage (fat %) group. Participants were classified into high fat (H-Fat) and low fat (L-Fat) groups using percent body fat cutoffs of ≥ 25% for males and ≥ 32% for females, as per the most recent guidelines of the American Society of Bariatric Physicians (ASBP; Seger et al., 2015), according to the W, L, and UW scores. The SDSVs consisted of the time-wise sums of all days of all participants belonging to a certain BMI-group. In this way, three new cumulative vectors, identifying the two BMI-groups for W, L, and UW, were obtained. Because of the voluntary input times and different eating habits, the patterns procured as just described above are not fully comparable between groups. This is because the results are a discontinuous sequence of values that do not take into consideration the temporal misalignment of the same eating event (e.g., dinner on Day 1 plus dinner on Day 2… plus dinner on Day *n*) occurring just a few minutes before or after that of the previous day. Therefore the next step was to make those sequences more time uniform. This was done by using a moving average filter. Therefore, the time portions of SDSVs with a higher concentration of high score values were clustered together and the time portions with a single score value were filtered out. The filtered score-vectors were no longer ranging from 1 to 10 as the input given by the participants in the smart phone application. Consequently, the vectors belonging to each BMI-group were normalised by their maximum and multiply by 10. This operation was conceivable under the assumption that in a standard day there is always at least one value equal to 10, the highest score possible. In this way two eating patterns, one for the L-Fat group and one for the H-Fat group, were identified for three vectors W, L, and UW.

Composite data analysis. A second phase of analysis was applied to the composite W, L, and UW vector data. The purpose of this phase was to identify both static and recurrence based relationships among these vectors. More specifically, the following steps were performed:

1. Covariance data analysis of the W, L, and UW vectors within each data set.
2. Static cross-correlation between respective vectors from the L-Fat and H-Fat data sets.
3. Determination of the vectors that share a common temporal profile with respect to the L-Fat and H-Fat sets.
4. Determination of the common, partial, and independent recurrence relationships.

A software tool written in VB.NET using Microsoft Visual Studio was developed to perform these four levels of decomposition and analysis.

3.4 Results

Data Cleaning

A total of 84 participants were initially recruited for this study. Of these, 28 cases provided insufficient data to be considered for inclusion (a 33.3% dropout rate). Of the remaining 56 cases, three individuals were excluded since their data were considered inaccurate and/or unrepresentative of the target population due to the following reasons:

- Fasting during the study period.
- Equipment malfunction resulting in an inaccurate fat percentage result.
- An unusually high 'wanting' frequency.

Therefore, the final sample consisted of 53 participants. A comparison of the 28 excluded participants and 53 included participants revealed no differences in gender distribution, $\chi^2(1) = 0.04$, $p = .84$, or mean age, $t(82) = 1.03$, $p = .30$. However, incomplete cases had higher BMIs on average (32.16 ± 9.84 kg/m^2) than did cases that provided complete data (28.11 ± 6.70 kg/m^2), $t(82) = 2.24$, $p = .03$. Thus, more overweight and obese individuals dropped out of the study than did normal-weight participants.

Description of Sample

Individuals were classified into high fat (H-Fat; $n = 20$) and low fat (L-Fat; $n = 33$) groups using percent body fat cutoffs of ≥ 25% for males and ≥ 32% for females, as per the most recent guidelines of the American Society of Bariatric Physicians (ASBP; Seger et al., 2015). (See Table 3-1) for the descriptive characteristics of the participants in each group.

There was no significant difference in age (39 ± 11 vs. 40 ± 10 years) or gender balance (84.8% vs. 70.0% female) between the L-Fat and H-Fat groups. As expected, BMI (24.04 ± 3.32 vs. 34.84 ± 5.29 kg/m^2) and body fat percentage (18.39% ± 6.57 vs. 42.34% ± 13.11) were significantly higher in the H-Fat group.

Table 3-1.

Descriptive characteristics for low fat (L-Fat) and high fat (H-Fat) groups.

	Grouped By Fat %		
Variable	L-Fat ($n = 33$)	H-Fat ($n = 20$)	*Statistical Comparison*
% Female (n)	84.8 (28)	70.0 (14)	$\chi^2(1) = 1.67, p = .20$
Age (years)	38.85 ± 11.36	40.25 ± 9.51	$t(51) = .46, p = .65$
BMI (kg/m^2)	24.04 ± 3.32	34.84 ± 5.29	$t(51) = 9.16, p < .001$
Body Fat %	18.39 ± 6.57	42.34 ± 13.11	$t(24.88) = 7.61^a, p < .001$

Note. [a]Unequal variances t-test is reported due to a significant Levene's test for equality of variances: $F = 10.44$, $p = .002$.

Frequency of Food Wanting and Eating Events

Food wanting frequency. ***Model specification.*** Box-plots displaying the distribution of total food 'wanting' frequency over the study period by group are shown in Figure 3.4. As evidenced in the figure, there was a wide variation in the 'wanting' frequencies for both groups, but the L-Fat group appeared to have a higher food 'wanting' frequency overall than the H-Fat group. This was assessed formally using a regression model. Food 'wanting' frequency consisted of discrete events; that is, the number of times an individual entered a perception of food 'wanting' during the two week period. Thus, the analysis of food 'wanting' frequency by group was conducted using a count regression model, starting with the Poisson model as the standard. Using a Poisson model resulted in a deviance ratio per *df* of 7.64, whereas a good model fit would be indicated by a ratio close to one. This indicates that the model was misspecified due either to a poor fit to the Poisson distribution and/or an over-dispersed response variable (Coxe, West, & Aiken, 2009). The negative binomial (NB) model was used to add an over-dispersion term and this resulted in significantly improved log-likelihood and information-criteria statistics compared to the Poisson model. The Lagrange Multiplier Test was used to formally test whether the negative binomial ancillary parameter equaled zero (i.e., whether the model reduced to a Poisson distribution). The test was statistically significant thereby rejecting the null hypothesis, $Z = 5.176, p < .001$, providing a strong indication that the negative binomial model provided a better fit to the data than the Poisson model. Finally, a likelihood ratio test (LRT) of the two nested models indicated a significantly better fit for the NB model (with the estimated ancillary parameter) compared to the Poisson, $\chi^2(1) = 115.54, p < .001$.

In summary, there was strong evidence that the NB model was more appropriate than the Poisson model for modelling food 'wanting' frequency. Therefore, the NB probability distribution was used to model food 'wanting' frequency with the NB ancillary parameter (k) estimated using the maximum likelihood (ML) of the log-likelihood function. Bootstrapping was conducted to provide a more stable indication of the parameter estimate confidence intervals due to the small sample size for the ML procedures. Bootstrapping was conducted using simple sampling with 5000 re-samples, and with bias-corrected and accelerated (BCa) confidence intervals.

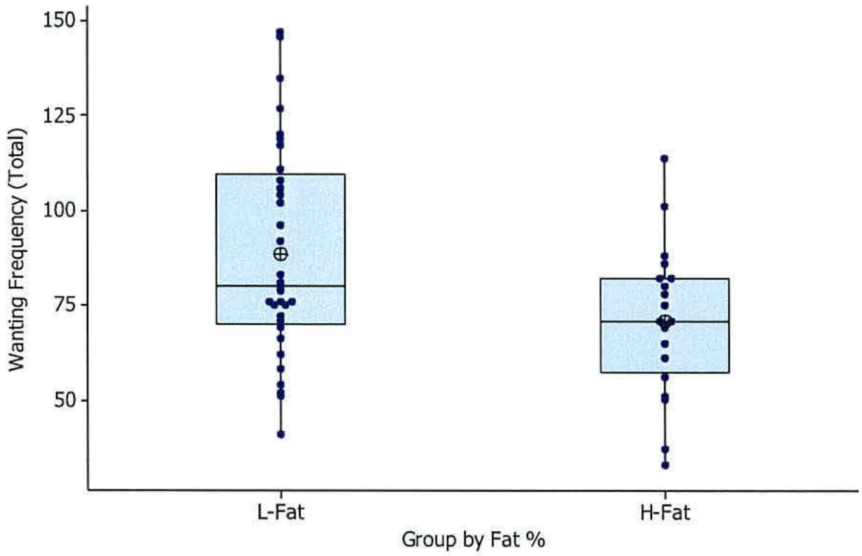

Figure 3.4. Box-plot distributions of 'wanting' frequency by fat % groups with individual (small blue circles) representing each participant. Boxes indicate the interquartile range and median for each group. The arithmetic mean is also displayed (open circles).

Wanting frequency by fat % group. The results of the NB regression analysis are shown in Table 3.2. Group was a statistically significant predictor of food 'wanting' frequency; the L-Fat group was associated with a 1.25 factor increase in food 'wanting' frequency compared to the H-Fat group (p = .009). The estimated mean for the L-Fat group was 88.7 food 'wanting' events, compared to 71.0 food 'wanting' events in the H-Fat group. Given that the study period was 14 days, this finding translated to about +1.3 'wanting' events/day for the L-Fat group.

Table 3-2.

Summary of findings for food wanting and eating frequency by fat % group.

	Parameter Estimates (Wald)			Model Information		Estimated Marginal Means	
Parameter	B (95% CI)	*p*	eB	LRT $\chi^2(1)$	Devianc e / *df*	L-Fat	H-Fat
DV: Wanting Frequency Model: NB (Log)				6.287, $p = .012$	1.073	88.70 (80.09, 98.23)	71.00 (62.15, 81.11)
Intercept	4.263 (4.144, 4.369)	< .001	71.000				
Group (L-Fat)	0.223 (0.059, 0.395)	.009	1.249				
k	.078 (.053, .099)						
DV: Eating Frequency Model: NB (Log)				5.735, $p = .017$	1.063	60.64 (55.38, 66.40)	50.20 (44.55, 56.56)
Intercept	3.916 (3.813, 4.012)	< .001	50.200				
Group (L-Fat)	0.189 (0.044, 0.341)	.014	1.208				
k	.054 (.005, .070)						
DV: Eating / Wanting Frequency Model: Binomial (Logit)				2.467, $p = .116$	NA	68.36 (66.66, 70.02)	70.70 (68.28, 73.01)
Intercept	0.881 (0.628, 1.191)	< .001	2.413				
Group (L-Fat)	-0.111 (-0.468, 0.251)	.117	.895				

Note. LRT = Likelihood-Ratio Test against the intercept-only model. *k* = NB ancillary parameter and confidence intervals are determined via 5000 BCa bootstrap samples.

Food eating frequency.

Model specification. A corresponding analysis to the 'wanting' event data was conducted on the total food eating frequency by group. Box-plots displaying the distribution of eating events over the study period by group are shown in Figure 2. Similar to the above finding, the L-Fat group also appeared to have a higher eating frequency than the H-Fat group. A count model regression was used to evaluate this observation. As was noted with the 'wanting' frequency data, the negative binomial model fitted the data better than the Poisson distribution. The Lagrange Multiplier Test null hypothesis that the NB ancillary parameter equaled zero was rejected, $Z = 4.307$, $p < .001$. Comparison of the two models with the LRT indicated a significantly better fit for the NB distribution, $\chi^2(1) = 45.13$, $p < .001$, and the information criteria were also significantly lower in the NB model.

As with the 'wanting' data, the NB probability distribution was used to model food eating frequency with the NB ancillary parameter (k) estimated using the maximum likelihood (ML) of the log-likelihood function. Bootstrapping was conducted to provide a more stable indication of the parameter estimate confidence intervals due to the small sample size for the ML procedures. Bootstrapping was conducted using simple sampling with 5000 re-samples, and with bias-corrected and accelerated (BCa) confidence intervals

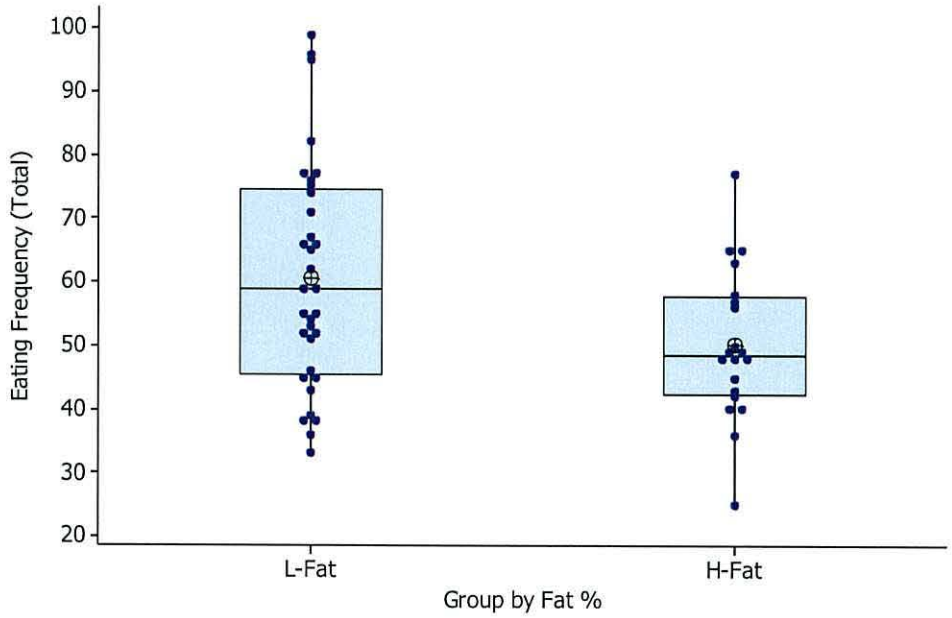

Figure 3.5. Box-plot distributions of eating frequency by fat % groups with individual symbols (with small circles) representing each participant. Boxes indicate the interquartile range and median of each group. The arithmetic mean is also displayed (open circles).Eating frequency by fat % group.

Eating Frequency by Fat % Group

The results of the NB regression analysis of eating frequency by group mirrored those obtained for the 'wanting' frequency data and are reported in Table 2. Group was a statistically significant predictor of food 'wanting' frequency; the L-Fat group was associated with a 1.21 factor increase in food 'wanting' frequency compared to the H-Fat group (p = .014). The estimated mean for the L-Fat group was 60.6 food eating events, compared to 50.2 food eating events in the H-Fat group, or about 10 more eating events over the 14 day study period (approximately 0.7 events/day).

Food eating and resisting frequency.

Model specification. Although eating frequency could be considered a count variable, it might be better conceptualised as a representation of one of two outcomes for each 'wanting' event: eat or not eat (resist). Thus, the proportions of 'wanting' scores that led to eating compared to 'wanting' scores that were resisted were examined in the two groups. This analysis was conducted using the binomial distribution and the logit link function (i.e., logistic regression) rather than using a count model. The dependent variable was the number of events that led to eating out of the total number of 'wanting' events.

Eating and resisting event proportions by fat % group. The analysis results are provided in Table 3.3. Figure 3.6 shows that there were 2927 recorded 'wanting' events in the L-Fat group of which 2001 events led to eating (68.4%). In the H-Fat group, participants ate in 1004 out of 1420 recorded 'wanting' events (70.7%). Analyses of these proportions under the binomial distribution (logit link function) indicated no significant differences between the proportions of eating and resisting frequencies by group (p =

.117).

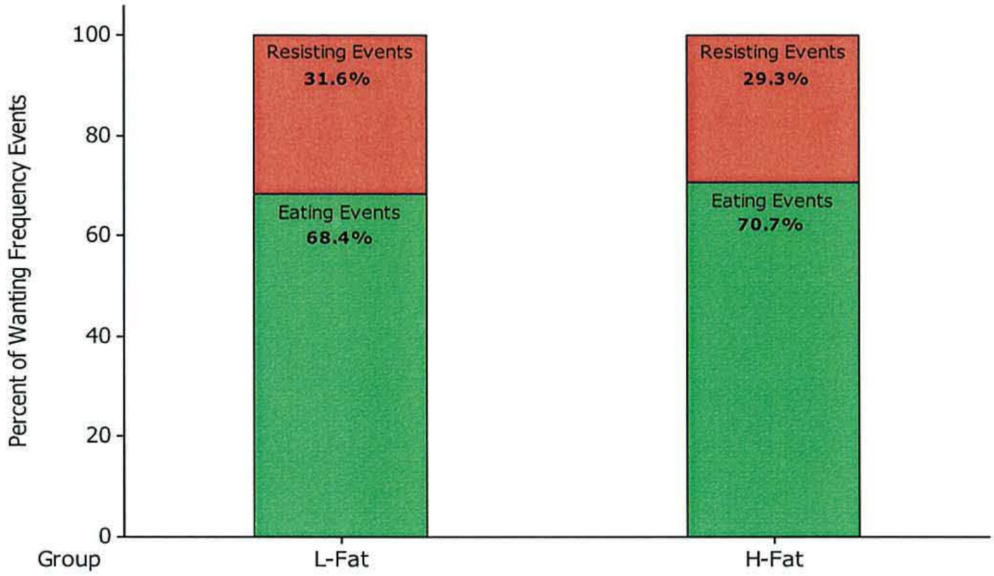

Figure 3.6. Eating and resisting events out of total food 'wanting' events for L-Fat and H-Fat groups

.Table 3-3

Eat.or.not.5 * Fat% groups n = 53 Crosstabulation

			Fat% groups n = 53		Total
			low fat	high fat	
Eat.or.not.5	Eat	Count	2001_a	1004_a	3005
		% within Fat% groups n = 53	68.4%	70.7%	69.1%
	Want but not eat	Count	926_a	416_a	1342
		% within Fat% groups n = 53	31.6%	29.3%	30.9%
Total		Count	2927	1420	4347
		% within Fat% groups n = 53	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Fat% groups n = 53 categories whose column proportions do not differ significantly from each other at the .05 level.

Summary of Frequency Results

In summary, analyses of the number of food events indicated that the L-Fat group recorded significantly more food 'wanting' events and more food eating events than did the H-Fat group. On average, L-Fat participants recorded 1.25 times as many 'wanting' events and 1.21 times as many eating events than the H-Fat group. Proportionally, 'wanting' that led to eating events, as opposed to food resisting events, were essentially equivalent in the H-Fat (70.7%) and L-Fat (68.4%) groups.

Rating of Events

Rating of food wanting and liking.

Model specification. As described in the methodology chapter, participants were asked to record the score of their food 'wanting' and 'liking' on a scale of 0 (*not at all*) to 10 (*very strongly*). Because all scores were rated on a commensurate scale, they could be subjected to a profile analysis, which is useful to examine whether the profiles of groups differ on a set of measures on the same scale (Tabachnick & Fidell, 2007). This method was used because the researcher was interested in the differences among groups, the difference between rating scores, and any interaction between group and rating scores. A profile analysis provides one method by which to examine these associations in a single analysis. Although the multivariate effects were of nominal interest, the researcher was primarily interested in comparing each rating type. Thus, the univariate contrasts were examined without undue regard for the multivariate findings, although the latter are reported for the sake of completeness.

Three separate sets of scores were of interest (Figure 3.6) and served as the dependent variables (DVs): rating scores for 'wanting' events that led to eating (WE), 'wanting' events that were resisted (WR), and participants' 'liking' scores (L) following meal consumption. Participants' average scores (by frequency) were used in the analysis to account for the different event rates. The factor was grouped by fat %.

Firstly, a number of assumptions of the analysis were evaluated to ensure that the findings obtained could be considered reliable (Tabachnick & Fidell, 2007). For one, there must be more participants in the smallest group than there are DVs; which was satisfied with $n = 20$ (H-Fat) and DVs = 3 for this analysis. Multivariate normality is required but, given that MANOVA is robust, normality of the sampling distributions is expected so long as there are more cases than DVs in the smallest group and the values of n are not highly unequal. MANOVA is highly sensitive to outliers; thus, univariate outliers were assessed using Z scores and multivariate outliers were assessed using Mahalanobis distances (D). One multivariate outlier was identified with $D = 14.26$, above the critical value of the χ^2 distribution with 3 df and $p < .001$ (12.84). Another case had a univariate Z score of -3.20 for WR and $D = 12.10$, which was close to the critical value of the χ^2 distribution. Thus, these two cases (both in the L-Fat group) were excluded before conducting the multivariate analysis. Homogeneity of variance–covariance is often assessed with Box's M test, although it is considered overly sensitive. The test was not statistically significant; thus, the null hypothesis that the observed covariance matrices of the DVs are equal across groups was not violated, Box's $M = 3.291$, $p = .802$. Univariate homogeneity of variance was also met for all three DVs using Levene's tests of equality of error variances (all p-values > .3). Linearity of the relationships among the DVs is also assumed and was evaluated by examining bivariate scatterplots between pairs of variables (see Figure 3.7). There were no indications of curvature in the relationships between the three rating scores. The strength of the intercorrelations between the three dependent variables was also noted to follow a logical pattern. The highest correlation was between the WE and L scores ($r = .68$) for ratings of the same foods (WE = anticipatory; L = reward). Intermediate in strength was the relationship between the two 'wanting' scores of WE and WR ($r = .56$). Finally, the lowest correlation was between ratings for the two discrepant scenarios of L and WR ($r = .33$).

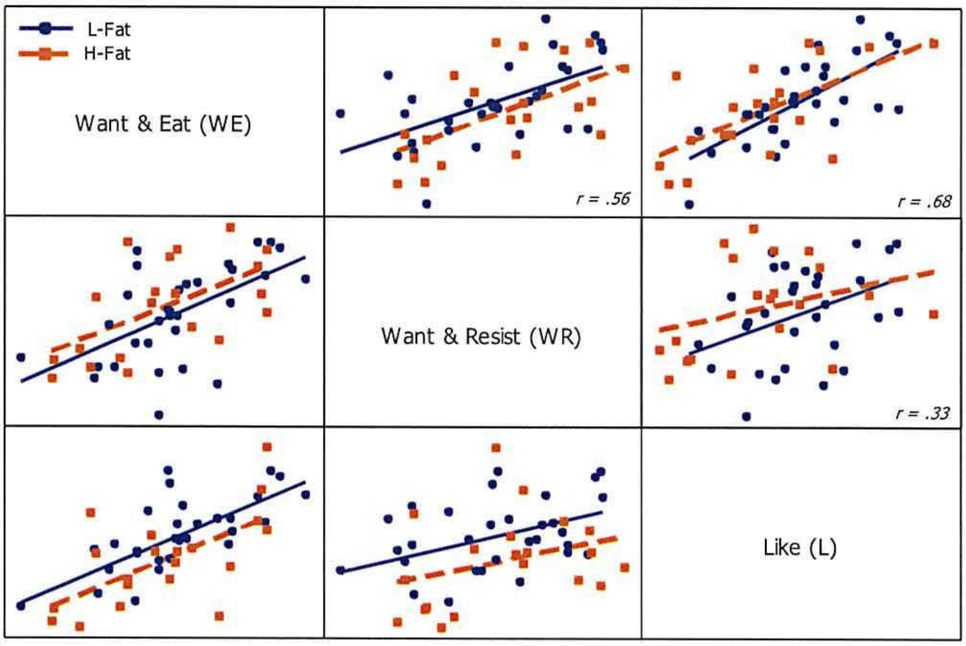

Figure 3.7. Scatterplot matrix with linear regression lines for three rating scores demonstrating linearity between pairs of DVs. Correlation coefficients for the full sample are reported above the diagonal ($N = 51$).

Rating scores by type and group.

The omnibus statistical measures from the MANOVA profile analysis are presented in Table 3 and the score profiles by group are shown in Figure 3.8. The tests of scores and scores by group are multivariate tests about adjacent segments of the profiles (e.g., the difference between WE and WR scores), whereas the test of group is a univariate test.

As seen in Figure 3.8, both groups had 'liking' scores (following food consumption) rated highest and 'wanting' events that were resisted (WR) rated lowest. The anticipatory rating of 'wanting' events leading to eating (WE) was midway between the two extremes. This effect is reflected in the significant multivariate effect of score ($p <$ .001), which indicated that one or more slope segments between scores differed from zero, with the groups combined. Although the chart suggested that the slope segments were steeper in the L-Fat group, this was not borne out in the test of parallelism. There was no significant multivariate interaction (p = .132) indicating that the slopes between adjacent scores were essentially parallel among groups.

Finally, the non-significant effect of group indicated that, on average, both groups scored similarly on the collected set of measures (p = .510).

Table 3.4.

Summary statistics for profile analysis of rating scores by group.

Parameter	*Wilks' λ*	*F*	*df*[a]	*p*	η^2_p
Score	.620	14.730	2, 48	< .001	.380
Score X Group	.919	2.117	2, 48	.132	.081
Group	--	0.441	1, 49	.510	.009

Note. [a]Two outliers were removed from the L-Fat group prior to conducting the analysis.

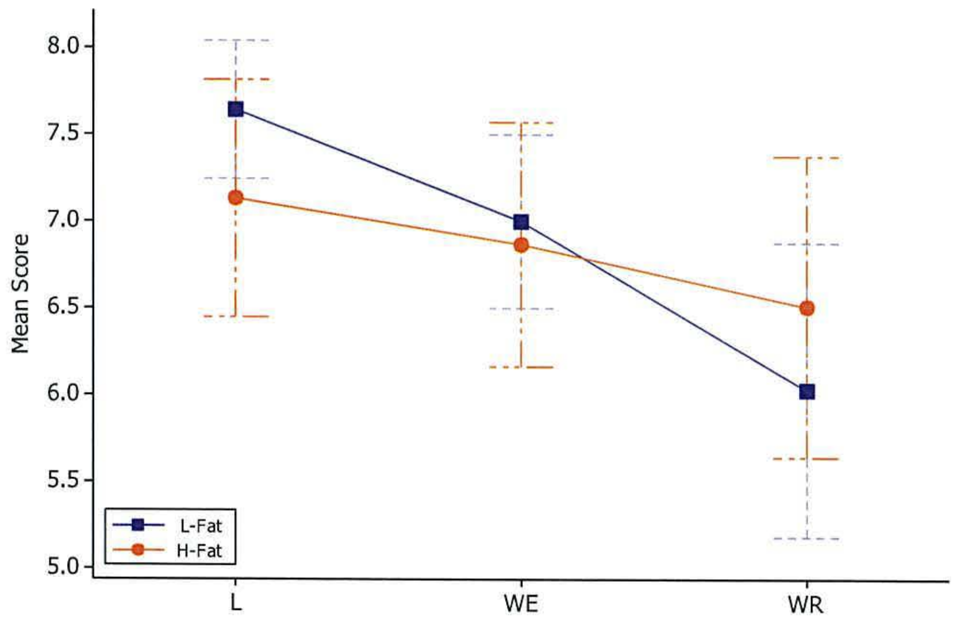

Figure 3.8. Mean rating scores with 95% bonferroni confidence intervals for 'liking' following consumption (L), 'wanting' events leading to eating (WE), and 'wanting' events that were resisted (WR).

As mentioned above, the *a priori* interest was in any differences between rating scores and among groups, which were investigated with planned contrasts between groups and rating scores (see Table 3-4). L-Fat participants as a group had higher L scores than H-Fat participants ($p = .052$). The two groups did not differ in their mean WE or WR scores. Comparisons between rating scores within groups revealed that all three scores were significantly different from one another in the L-Fat group; that is, L > WE > WR (all *p*-values < .001). In contrast, none of the scores in the H-Fat group differed significantly from one another (*p*-values > .1, for all comparisons). These result was confirmed when further analysis were conducted by categorizing the groups depending on BMI (see table 3-5). A significant difference was observed only when liking scores were considered, with the obese participants liking their food less than their lean counterparts. Although both groups gave on average higher scores for liking than wanting, this difference was significantly reduced in the obese group. (See Table 3-5)

Table 3-4. Descriptive statistics by group and comparisons between rating scores.

Score	*L-Fat (n = 31)*[a]	*H-Fat (n = 20)*	*Difference between Groups (95% CI)*
	M ± SD		
L	7.66 ± .83	7.14 ± 1.04	.52 (-.01, 1.05) $p = .052$
WE	7.07 ± .94	6.87 ± 1.07	.20 (-.37, .77) $p = .485$
WR	6.32 ± 1.29	6.54 ± 1.29	-.22 (-.96, .53) $p = .564$
	Difference between Rating Scores (95% CI)		
L–WE	.59 (.25, .93) $p < .001$	.27 (-.15, .69) $p = .361$	–
L–WR	1.34 (.77, 1.91) $p < .001$	.60 (-.10, 1.31) $p = .119$	–
WE–WR	.75 (.26, 1.23) $p < .001$	.33 (-.27, .93) $p = .534$	–

Note. L = 'liking' score, WE = 'wanting' score leading to eating. WR = 'wanting' score that was resisted. 95% confidence intervals for the differences (Bonferroni) are reported in parentheses.
[a]Two outliers were removed from the L-Fat group before conducting the analysis.

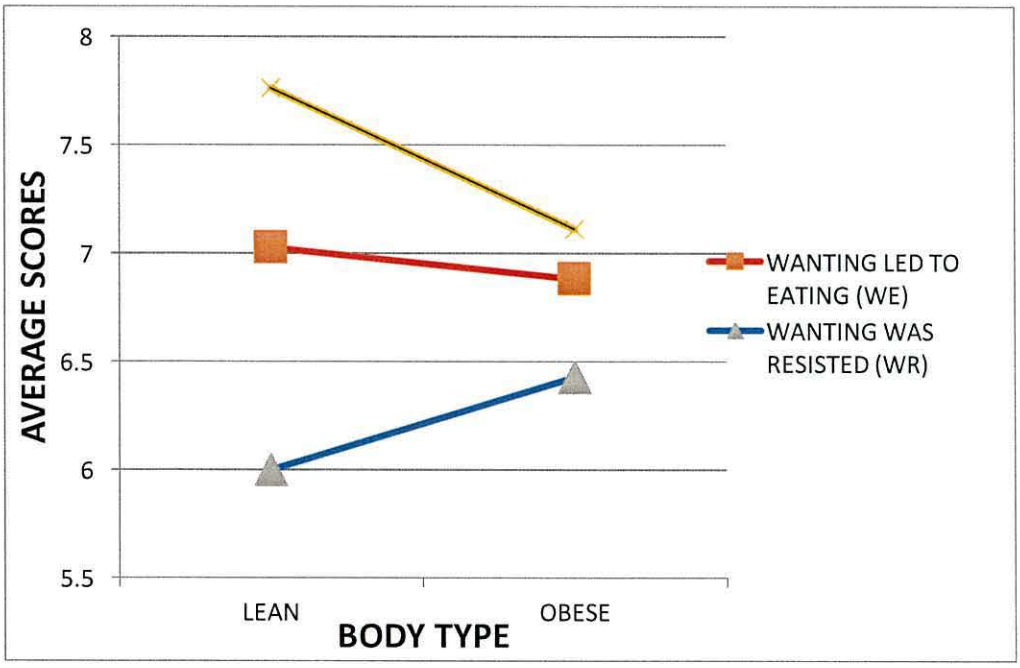

Figure 3.9. Average score between L-Fat and H-Fat

Table 3-5

Food wanting, eating and liking frequencies and scores between obese and Lean individuals

	Lean (BMI 18.5-24.9) Mean (SD)	Obese (BMI>30) Mean (SD)
Wanting frequency/day	6.18 (1.95)	5.25 (1.43)
Eating frequency/day	4.35 (1.32)	3.68 (0.78)
Resisting frequency/day	1.82 (1.47)	1.57 (1.01)
Duration of eating/ event (mins)	19:09 (8:15)	16:26 (7:01)
Wanting score	6.76 (1.08)	6.72 (1.07)
Wanting score leading to eating	7.03 (1.08)	6.88 (1.11)
Wanting score not leading to eating	6.00 (1.82)	6.43 (1.23)
Liking score	7.76 (0.78)	7.11 (1.10)*
Liking - wanting score (difference)	1.00 (0.87)	0.39 (0.70)*

- $p < 0.05$

Summary of Rating Score Analyses

To summarise, three types of rating scores were examined with respect to the mean rating levels and differences among groups. Scores were averaged for each participant across their respective number of events to provide an unbiased comparison of ratings rather than frequencies. 'Wanting' scores leading to eating events (WE) were differentiated from 'wanting' scores that did not lead to eating ('wanting' but resisting events, WR). 'Liking' scores after eating events (L) were also recorded. Large, positive linear bivariate relationships were observed between participants' anticipatory 'wanting' scores (WE) and their reward-based 'liking' scores (L) ($r = .68$).

The effect of type of rating score was statistically significant and the three rating types were ranked from highest to lowest as follows: L > WE > WR. 'Liking' scores were higher than eating scores, meaning that participants rated their food reward after consumption to be higher than their anticipatory rating (WE). As would be expected intuitively, 'wanting' events leading to eating (WE) were rated more highly than 'wanting' events that were resisted (WR). Importantly, the mean score differences were only statistically significant in the L-Fat group. Although the H-Fat group showed the same pattern, none of their scores were significantly different from one another. This suggests that H-Fat participants provided a relatively low differentiation of ratings by type of event.

Instruments to Compare Food Cravings and Attitudes

Food cravings questionnaire – Trait version. All participants completed the Food Cravings Questionnaire – Trait Version (FCQ-T), which consisted of 39 items rated on a frequency scale from 1 (*never*) to 6 (*always*) (Cepeda-Benito et al., 2000). Mean scores on the nine FCQ-T factors and the total scores by group are reported in Table 3-6. The mean FCQ-T total score in the H-Fat group of 151.35 ± 33.87 was significantly higher than that observed in the L-Fat group, 125.39 ± 29.31, $p = .005$. Higher scores are indicative of more frequent and severe food cravings.

Many of the individual factors were significantly different or suggestive of higher scores in the H-Fat group. Since the number of items per factor score ranged from three to seven, Figure 6 provides the mean scores by group but averaged per item to allow a visual comparison between the factor scores and the groups on a common scale between 1 and 6.

Both groups showed a very similar pattern of responding on the factors. Lack of control (4. LACK CO, Figure 3.10) was given the highest rating by both groups, and negative reinforcement (3. NEG R) was rated lowest by both groups. Divergence between groups was most notable for emotions before or during craving or eating (7. EMOTION), which was over a point higher for H-Fat compared to L-Fat participants (4.17 vs. 3.07).

Table 3-6.

FCQ-T Scores by Group.

FCQ-T Factor	*L-Fat*	*H-Fat*	*Comparison among Groups (df = 51)*
1. Having Intentions and Plans to Consume Food	10.85 ± 3.55	12.45 ± 3.00	$t = 1.69, p = .10$
2. Anticipation of Positive Reinforcement That May Result From Eating	15.48 ± 4.68	18.30 ± 4.26	$t = 2.20, p = .03$
3. Anticipation of Relief From Negative States and Feelings as a Result of Eating	7.67 ± 3.01	9.40 ± 3.60	t = 1.89, $p = .07$
4. Lack of Control Over Eating	15.52 ± 4.85	18.50 ± 3.86	$t = 2.34, p = .02$
5. Thoughts or Preoccupation With Food	19.06 ± 6.66	22.75 ± 10.06	$t^a = 1.46, p = .16$ (df = 29.21)
6. Craving as a Physiological State	15.18 ± 2.73	16.00 ± 3.89	$t = .90, p = .37$
7. Emotions That May Be Experienced Before or During Food Cravings or Eating	18.39 ± 6.62	25.00 ± 6.81	$t = 3.48, p = .001$
8. Cues That May Trigger Food Cravings	13.30 ± 5.63	16.60 ± 5.96	$t = 2.02, p = .048$
9. Guilt From Cravings and/or for Giving Into Them	9.94 ± 4.30	12.35 ± 3.36	$t = 2.14, p = .04$
FCQ-T Total	125.39 ± 29.31	151.35 ± 33.87	$t = 2.95, p = .005$

[a]Unequal variances t-test is reported due to a significant Levene's test for equality of variances: $F = 5.60, p = .02$.

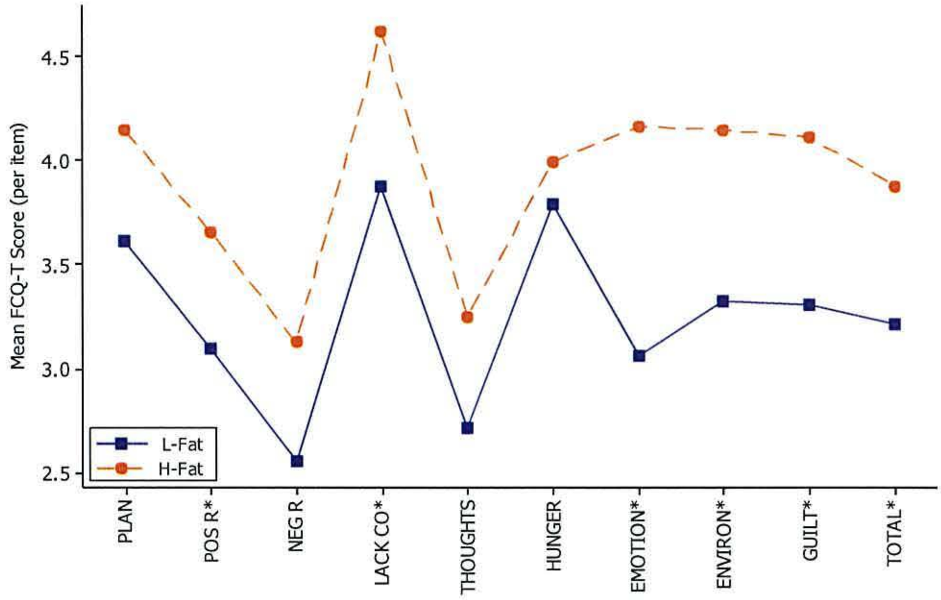

Figure 3.10. FCQ-T factor and total scores by group. Both groups showed a similar pattern across the subscales, but the H-Fat group had uniformly higher scores than the L-Fat group (*$p < .05$).

More over a partial correlation was conducted to assest and compare between the FCQ_T dimension and phone application variables in order to assess the validity of the phone application measurements.

In the H-group, analysis of the correlation between craving trait dimensions and *unresisted wanting fraction* showed significant ($p<0.05$) positive correlations for the FCQ-T domains T2 (*positive reinforcement*) r= 0.588, T5 (*thoughts of food*) r=0.529, T8 (*emotions induced by eating*) r=0.623, and FCQ-T sum r= 0.553. Consequently, for the H-group, the higher the levels in craving traits the less food wanting was resisted. The L-group, however, did not show any significant correlations between *resisted wanting* and craving traits. *Unresisted wanting fraction* was significantly ($p<0.05$) correlated with BMI ($r=0.613$) and body fat % ($r=0.454$) in the H- group but not in the L- group. Moreover, the importance of craving traits for the H-groups' wanting frequencies was emphasized by the significant ($p<0.05$) correlation of *unsuccessful wanting* frequencies with several craving traits (T2: $r=-0.616$, T5: $r=-0.447$, T8: $r=-0.583$, FCQ-Tsum: $r=-0.478$), while no correlations were detected with *successful wanting* frequencies; no significant associations were reported for the L-group. In summary, *unsuccessful wanting* frequencies and *unresisted wanting fraction* were strongly correlated with craving traits, and body characteristics, in the H-group but not in the L-group. (see table 3.7)

Table 3.7 **Partial Correlation between FCQ_T dimensions and Phone Application variables**

Group By Fat%	Variables		BMI	Fat%	unresisted wanting fraction	unsuccessful wanting frequencies
Low Fat Group	FCQ_T_SUM	Correlation	.109	.236	-.197	.108
		Significance (2-tailed)	.546	.187	.272	.548
		df	31	31	31	31
	FCQ_T1 HAVING INTENTIONS AND PLANS TO CONSUME	Correlation	-.036	.154	-.167	.082
		Significance (2-tailed)	.840	.391	.352	.649
		df	31	31	31	31
	FCQ_T2 ANTICIPATON OF POSITIVE REOFORCEMENT FROM EATING	Correlation	.047	.076	-.064	-.057
		Significance (2-tailed)	.796	.674	.723	.754
		df	31	31	31	31
	FCQ_T3 ANTICIPATION OF RELIEF FROM NEGATIVE STATES AND FEELINGS FROM EATING	Correlation	.112	.258	-.197	.080
		Significance (2-tailed)	.536	.148	.272	.658
		df	31	31	31	31
	FCQ_T4 CUES THAT MAY TRIGGER FOOD CRAVING	Correlation	.278	.328	-.421	.316
		Significance (2-tailed)	.118	.063	.015	.073
		df	31	31	31	31
	FCQT5 THOUGHTS OR PREOCCUPATION WITH FOOD	Correlation	.056	.123	-.124	.111
		Significance (2-tailed)	.758	.496	.491	.538
		df	31	31	31	31
	FCQT6 CRAVING AS A PHYSIOLOGICAL STATE	Correlation	-.027	-.108	-.110	-.030
		Significance (2-tailed)	.882	.550	.542	.867
		df	31	31	31	31
	FCQT7 LACK OF CONTROL OVER EATING	Correlation	.064	.194	-.013	-.027
		Significance (2-tailed)	.723	.280	.941	.883
		df	31	31	31	31
	FCQ_T8 EMOTION THAT MAY BE EXPERIENCED BEFORE OR DURING FOOD CRAVINGS OR EATING	Correlation	.094	.116	-.113	.099
		Significance (2-tailed)	.604	.521	.532	.583
		df	31	31	31	31
	FCQ_T9 GUILT FROM CRAVING AND/OR FOR GIVING INTO THEM	Correlation	.041	.276	-.090	.079
		Significance (2-tailed)	.821	.120	.619	.663
		df	31	31	31	31
High Fat Goup	FCQ_T_SUM	Correlation	.269	.266	.553	-.4785
		Significance (2-tailed)	.252	.257	.012	.033 *
		df	18	18	18	18
	FCQ_T1 HAVING INTENTIONS AND PLANS TO CONSUME	Correlation	.075	.082	.149	.018
		Significance (2-tailed)	.755	.732	.531	.941
		df	18	18	18	18

	FCQ_T2 ANTICIPATON OF POSITIVE REOFORCEMENT FROM EATING	Correlation	.299	.144	.588	-.616
		Significance (2-tailed)	.200	.544	.006 *	.004 *
		df	18	18	18	18
	FCQ_T3 ANTICIPATION OF RELIEF FROM NEGATIVE STATES AND FEELINGS FROM EATING	Correlation	.137	.004	.283	-.272
		Significance (2-tailed)	.566	.985	.227	.245
		df	18	18	18	18
	FCQ_T4 CUES THAT MAY TRIGGER FOOD CRAVING	Correlation	-.015	.073	.411	-.388
		Significance (2-tailed)	.949	.761	.072	.091
		df	18	18	18	18
	FCQT5 THOUGHTS OR PREOCCUPATION WITH FOOD	Correlation	.352	.338	.529	-.447
		Significance (2-tailed)	.128	.145	.017 *	.048 *
		df	18	18	18	18
	FCQT6 CRAVING AS A PHYSIOLOGICAL STATE	Correlation	.357	.495	.208	-.256
		Significance (2-tailed)	.122	.026 *	.378	.276
		df	18	18	18	18
	FCQT7 LACK OF CONTROL OVER EATING	Correlation	.180	.166	.422	-.254
		Significance (2-tailed)	.448	.483	.064	.280
		df	18	18	18	18
	FCQ_T8 EMOTION THAT MAY BE EXPERIENCED BEFORE OR DURING FOOD CRAVINGS OR EATING	Correlation	.201	.223	.623	-.583
		Significance (2-tailed)	.396	.345	.003 *	.007 *
		df	18	18	18	18
	FCQ_T9 GUILT FROM CRAVING AND/OR FOR GIVING INTO THEM	Correlation	-.053	.019	.133	-.132
		Significance (2-tailed)	.823	.935	.575	.580
		df	18	18	18	18

* significant (p<0.05)

Implicit and explicit attitude scores. Participants also completed the Implicit Attitude Test (IAT) and an explicit attitude questionnaire (Table 3-7). Implicit attitude scores did not differ between the groups (p = .62). However, explicit attitude scores were significantly higher in the L-Fat group than the H-Fat group (49.39 vs. 45.05; p = .006).

Table 3-8.

Implicit and Explicit Attitude Scores by Group.

Attitude Test	*L-Fat*	*H-Fat*	*Comparison among Groups (df = 51)*
Implicit	1.17 ± .21	1.14 ± .24	t = 0.50, p = .62
Explicit	49.39 ± 5.25	45.05 ± 5.58	t = 2.85, p = .006

The analyses reported above examined separately the associations between Fat% and demographic variables, event frequencies, rating scores, and attitudes. The purpose of the following set of analyses was to examine the associations between all variables of interest, and to determine whether a predictive model could be created to reliably predict the reward from food, as assessed by 'liking' (L) scores, from a set of pertinent variables.

The intercorrelation matrix between all variables of interest is reported in Table 3-8. For these analyses, body fat percentage was evaluated as a continuous variable rather than as dichotomised into L-Fat and H-Fat groups. The natural log of the 'wanting', eating, and resisting frequencies were used due to skewness of the event data. A number of noteworthy correlations were observed.

For one, body fat percentage (fat %) as a continuous variable was significantly and negatively correlated with the frequency of food 'wanting' events, food 'liking' scores following consumption, and explicit attitudes. Thus, individuals with a higher fat % recorded fewer 'wanting' events, lower 'liking' scores, and lower explicit attitude scores.

A significant positive correlation between fat % and FCQ-T scores indicated that higher fat respondents also had higher food cravings, as assessed by the FCQ-T total score. These results were very similar to those obtained when fat % was dichotomised into L-Fat and H-Fat groups, except that fat group was a significant predictor of eating event frequency, which was not observed in this correlational analysis.

In addition to fat %, the demographic variables of sex and age were also examined. Sex was negatively correlated with eating frequency; females recorded more eating events than did males. Age was not significantly correlated to any of the study variables.

The frequencies of 'wanting', eating, and resisting events (natural logarithms) were correlated with one another but did not show any significant associations with the other variables in the study.

Rating scores of W, WE, WR, and L were inter correlated with each other in the expected patterns. The rating scores for eating events (i.e., W, WE or L scores) were also significantly moderately correlated with the IAT scores. Respondents that reported a higher desire for, or reward from, food also had higher scores on the IAT. Finally, the IAT and FCQ-T scores were inversely correlated; higher scores on the IAT were associated with lower FCQ-T total scores, and vice versa.

Table 3-9

Intercorrelation Matrix between Demographic Variables, Event Frequencies, Rating Scores, and Instrument Scores.

No.	Variable	*1* Fat%	*2* BMI	*3* Sex	*4* Age	*5* Freq.W	*6* Freq.E	*7* Freq.R	*8* W.Sc	*9* WE.Sc	*10* WR.Sc	*11* L.Sc	*12* FCQ	*13* IAT	*14* Exp
1	Fat%	--	**			*						**	**		**
2	BMI	**	--			**						**	**		**
3	Sex (1=F, 2=M)	-.061	.099	--			**								
4	Age	.084	.144	-.032	--										
5	Freq Wanting (Ln)	-.309	-.324	-.256	-.131	--	***	***							
6	Freq Eating (Ln)	-.228	-.226	-.362	.146	.768	--								
7	Freq Resisting (Ln)	-.248	-.226	.024	-.269	.708	.183	--							
8	Wanting Score (All)	.013	-.044	-.029	.000	-.224	-.207	-.117	--	***	***	***		**	
9	Want-Eat Score (WE)	-.048	-.104	-.071	-.038	-.123	-.199	.008	.944	--	***	***		*	
10	Want-Resist Score (WR)	.103	.068	.021	-.038	-.205	-.233	-.062	.721	.544	--	*			
11	Liking Score (L)	-.373	-.360	.009	.245	.040	.048	.037	.608	.663	.274	--		**	
12	FCQ-T Total	.439	.409	-.185	-.104	-.151	-.103	-.105	.012	-.036	.187	-.247	--	*	
13	IAT	-.018	-.028	.078	.259	-.012	.065	-.050	.353	.333	.115	.365	-.312	--	
14	Explicit	-.389	-.366	-.076	.179	.106	.146	.061	.031	.051	-.053	.213	-.155	-.047	--

Note. N = 53. Significance values are indicated by asterisks above the diagonal.
* p < .05, ** p < .01, *** p < .001.

1.

Model specification. In order to examine a predictive model of reward from food, variables were entered in a series of steps hierarchically based on theoretical and logical merit. Four blocks were entered in turn. Within each block, a stepwise selection of variables was conducted. Due to the small sample size and the exploratory nature of this analysis, liberal probabilities of F were used (entry $p = .075$, removal $p = .15$). The four blocks were:

- Block 1. Demographic variables were entered in the first block, since these attribute variables are inherent to the respondents. Variables considered: fat %, age, and sex.
- Block 2. Attitude scores at pre-test were entered in the second block, representing pre-existing attitudes, perceptions, and beliefs about food. Variables considered: FCQ-T total, IAT, and explicit scores.
- Block 3. In the third block, the natural logarithms of three event variables ('wanting', eating, resisting) were considered. Although redundant and singular if entered simultaneously, the stepwise procedure ensured that only the most useful predictor(s) would be entered.
- Block 4. The final block consisted of the rating scores – ratings of 'wanting' leading to eating (WE) and of 'wanting' leading to resisting (WR). These rating scores were entered last since, by virtue of the study design, respondents did not provide ratings without entering event data (Block 3).

Prediction of Food Reward (Liking)

The results from the regression procedure described above resulted in four predictors being entered into the model. The final step of the hierarchical regression is provided in Table 3-9. In Block 1, fat % was entered first ($\Delta R^2 = .139$), followed by age ($\Delta R^2 = .077$). In Block 2, the IAT score was entered as a significant predictor ($\Delta R^2 = .088$). No frequency data met criteria to enter in Block 3. In the final block, the WE rating scores were entered in the model and accounted for a large proportion in R^2 ($\Delta R^2 = .347$). This is not surprising given that the ratings are on the same meal events (i.e., WE = anticipatory rating, L = reward rating). Thus, the final model contained fat %, age, IAT scores, and WE scores. The variance in IAT scores was later subsumed by the WE scores and, thus, it was no longer a significant predictor in the final model. However, it was retained in the results presented in the table since, in the absence of anticipatory rating scores, IAT scores were a significant predictor of food reward scores (β = .307 in Model 3 vs. β = .075 in Model 4).

In summary, a model was constructed to predict food reward, or 'liking' scores, from demographic variables, attitudes towards food, food 'wanting' and eating event frequencies, and anticipatory ratings. Variables were selected using a combination of theoretical/logical entries in blocks, combined with statistical criteria within blocks (stepwise entry/removal). The final model included four predictors: body fat % (β = -.365), age (β = .280), IAT scores (β = .075), and anticipatory ratings of foods (β = .631). Discounting the anticipatory ratings as a covariate, higher food reward was therefore predicted by a lower body fat %, older age, and higher implicit attitude scores. Although stepwise regression methods are likely to capitalise on chance variance within the sample and may not be replicable (Tabachnick & Fidell, 2007), the model provides an impetus for examining the predictors of food reward in real life situations.

Table 3-10.

Stepwise Hierarchical Prediction of Liking Scores from Study Variables (Final Step).

		Parameter Estimates			*Model Improvement*	
Order	Parameter	*B* (95% CI)	β	*p*	ΔR^2	$p\ \Delta F$
DV: Liking (L) Rating Scores						
1	Fat %	-.023 (-.033, -.012)	-.365	< .001	.139	.006
2	Age	.024 (.009, .040)	.280	.003	.077	.032
3	IAT	.321 (-.489, 1.130)	.075	.430	.088	.016
4	WE Scores	.572 (.406, .738)	.631	< .001	.347	.000
	Intercept	2.758 (1.416, 4.101)		< .001		

Note. Final model $F(4, 48) = 22.41, p < .001$; $R^2 = .651$, Adj. $R^2 = .622$.

Times Series Result

Composite data analysis.

A second phase of analysis was applied to the composite W, L, and UW vector data. The purpose of this phase was to identify both static and recurrence based relationships among these vectors. More specifically, the following steps were performed:

Covariance data analysis of the W, L, and UW vectors within each data set.

1. Static cross-correlation between respective vectors from the L-Fat and H-Fat data sets.
2. Determination of the vectors that share a common temporal profile with respect to the L-Fat and H-Fat sets.
3. Determination of the common, partial, and independent recurrence relationships.

A software tool written in VB.NET using Microsoft Visual Studio was developed to perform these four levels of decomposition and analysis.

Static phase covariance analysis. A static phase covariance analysis was performed among the composite vector elements within a given data set. The term static means there is no relative time shifting of these composite vectors with respect to each other. In this analysis, a three-by-three covariance matrix was made with respect to the composite W, L, and UW vectors independently for each of the L-Fat and H-Fat data sets. This static analysis asserts a synchronised correlation of the vector time profiles within each data set. The results of this analysis showed the following mutual correlations:

Mutual Correlations in H-Fat Group:

W and UW: 0.798

W and L: 0.928

UW and L: 0.757

Mutual Correlations in L-Fat Group:

W and UW: 0.849

W and L: 0.945

UW and L: 0.826

A second form of static phase covariance analysis was performed for each composite vector element with respect to the L-Fat and H-Fat data sets. This resulted in three two-by-two covariance matrices:

L-Fat and H-Fat Mutual Correlations:

W Vector: 0.824

UW Vector: 0.844

L Vector: 0.906

The following plot (Figure 3.11) illustrates the mutual correlation of the W vector between the H-Fat W vector and the L-Fat W vector:

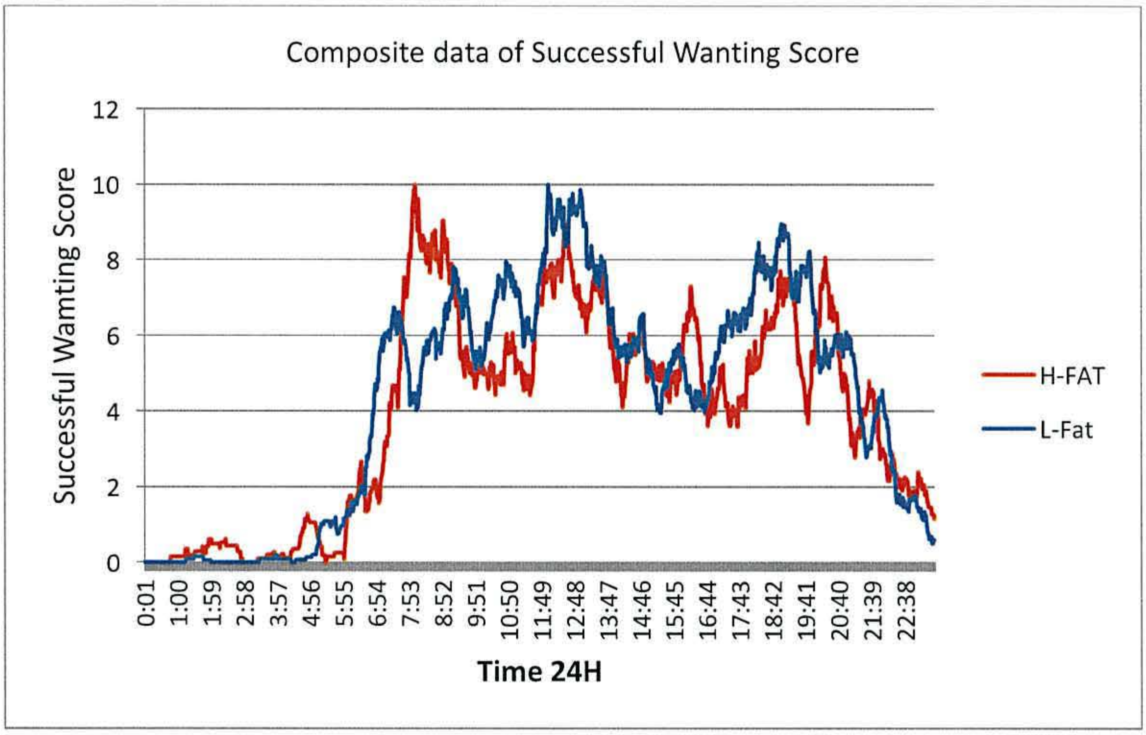

Figure 3.11. The mutual correlation of the W vector between the L-Fat and H-Fat sets.

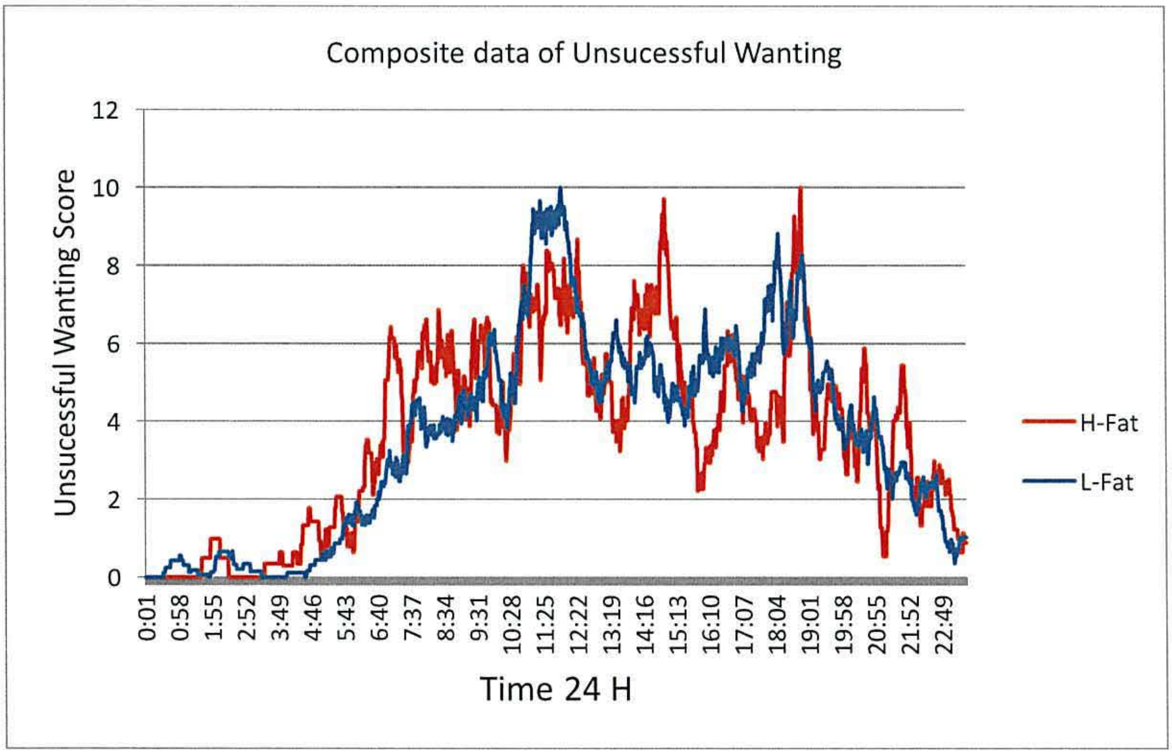

Figure 3.12. The UW vector is illustrated for the L-Fat and H-Fat sets

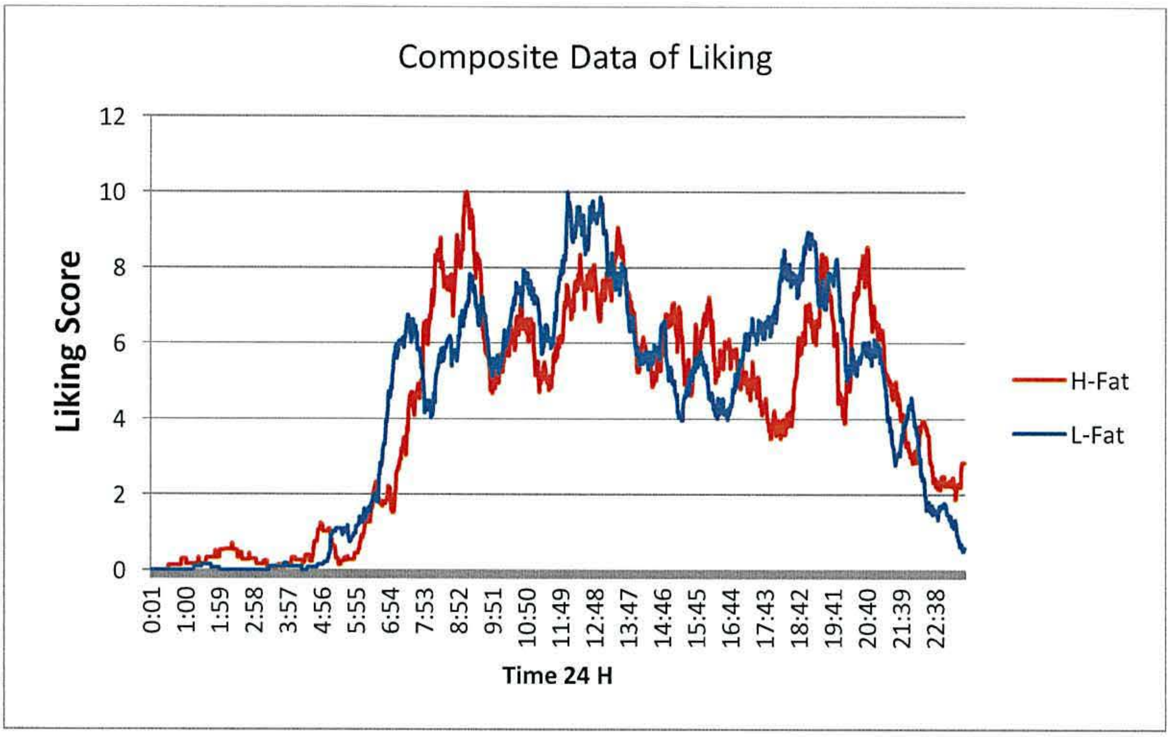

Figure 3.13. The L vector is illustrated for the L-Fat and H-Fat sets.

Recurrence analysis using autocorrelation mode tracking. The static phase analysis previously discussed was based on applying standard covariance calculations. For recurrence analysis purposes, however, the mutual and independent periodicity relationships were analysed using autocorrelation mode tracking analysis.

The array of correlation results is often called the auto-covariance matrix, whereby the inner product (correlation) of all shifted vector sequences is determined with respect to the original non-shifted sequence. Since the window used is finite, a sliding window correlation is performed for each shift index (lag). The characteristic modes derived from this analysis are the local peaks, as seen in the lag profile. Determining the peak autocorrelation associated lag over time is referred to here as 'mode tracking'. The time reference for the mode is determined by the relationship of the time of the input autocorrelation to the center time of the sliding window.

As illustrated in Figure 3.14, the auto-cross variance was evaluated for 48 time-centered windows spaced 30 min apart. The horizontal axis represents the mode tracked lag value that is associated with the peak for each 30 min interval auto cross-covariance set.

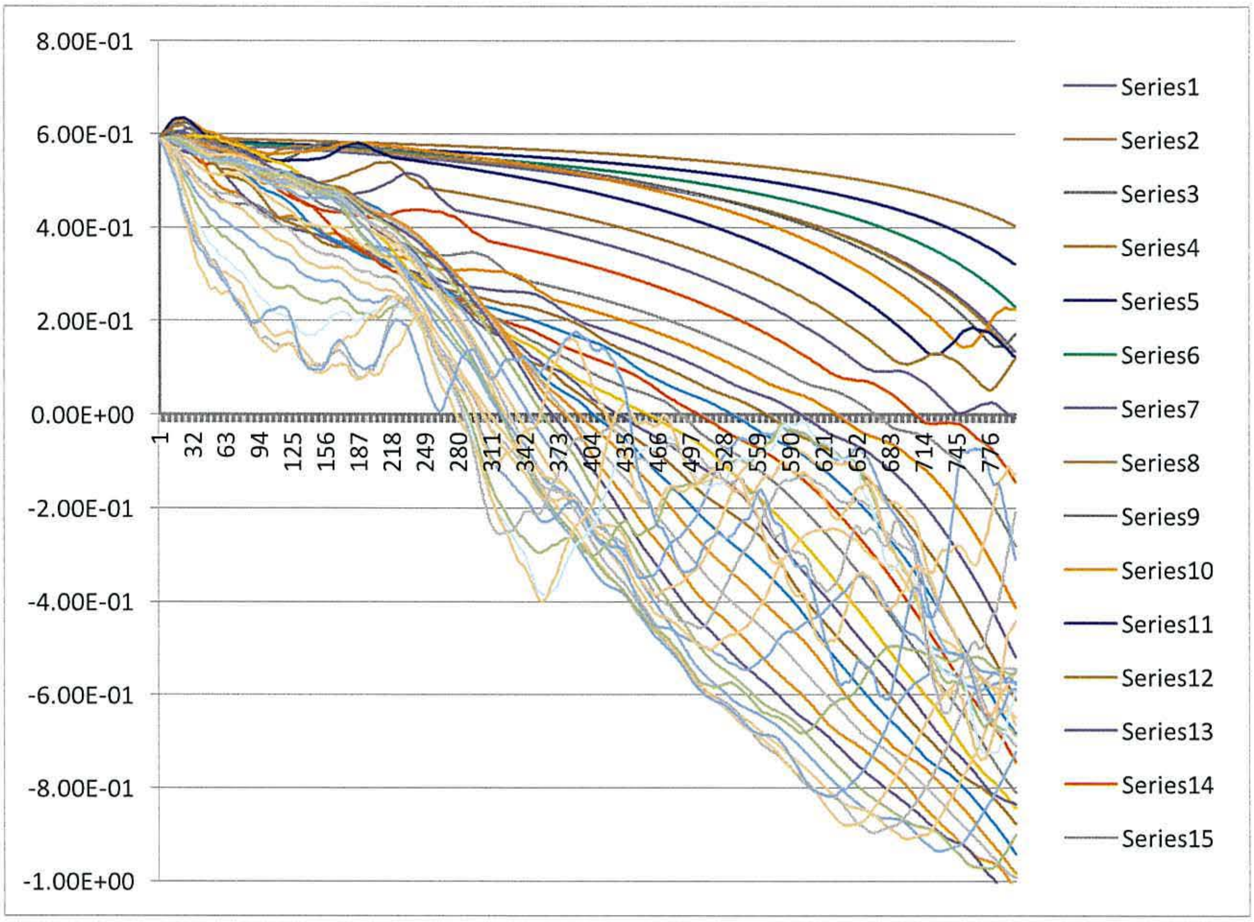

Figure 3.14. the auto-cross variance

The autocorrelation sample interval (of 1 min) was the same interval used to represent the composite vector data. The block size of 1000 samples is a sliding window that is initialised at 0:00 hr (after midnight) with a range of lags ranging from 0 to 800 min. Since input values initially represent a small portion of the large 1000 sample sliding window, the resulting autocorrelation values were normalised and mapped to center time correcting for the non-zero input locations. This assumption was valid because the mode processing was based on the majority of the non-zero data. As a result, a delay occurs when comparing the time of the center of the window relative to the centroid time for the sample times processed. In addition to a time correction after initialisation, a second correction is also applied at time 16:40, since the sliding window begins to extend beyond the maximum time period (24:00).

Figure 3.15 shows the delay correction plotted against time for the computed autocorrelation mode. The vertical axis is the delay correction in hours applied to the time (on the horizontal axis) that the autocorrelation mode center window time is evaluated.

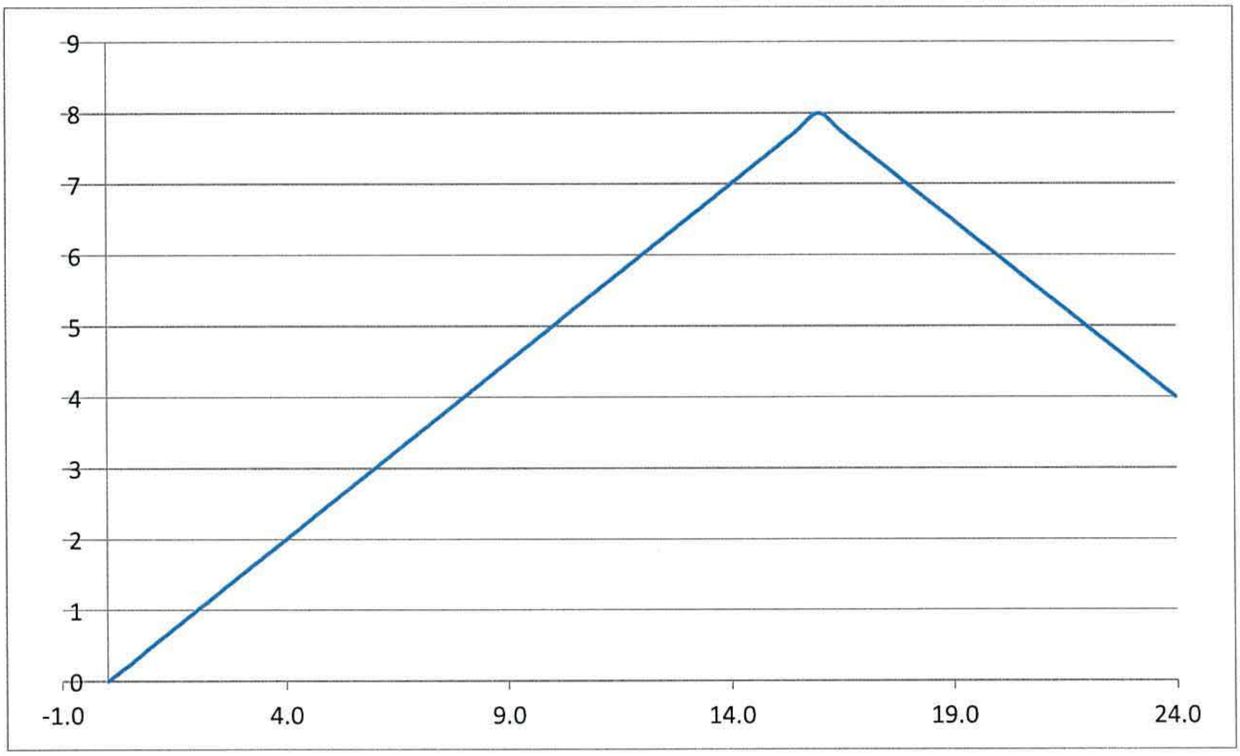

Figure 3.15. delay correction plotted against time for the computed autocorrelation mode..

Difference analysis applied to independent recurrence patterns. The prior dependent analysis of combined vectors from different data sets is useful for identifying commonalities. Performing mode tracking of each data set vector independently, however, is important for identifying the dissociation and differences in patterns.

Case independent UW vectors. Autocorrelation, mode tracking, and window lag correction were performed independently on the UW vectors for both groups. The mode period for L-Fat unsuccessful 'wanting' starts at 2 a.m. for a period of 90 min and jumps to more than 275 min approximately at 6 a.m. Concurrently, the mode period for H-Fat unsuccessful 'wanting' exceeds a pattern of 200 min over a slightly longer duration. A mode period of 50 min defines the obese 'wanting' sequence, which converges with the lean 'wanting' at 2 p.m. to 7:30 p.m. Obvious differences in the recurrence patterns include a delay in the dominant morning UW pattern, which has a shorter duration that repeats almost every 300 min instead of every 180 min. The H-Fat afternoon pattern starts earlier and is sustained longer with a repetition interval of 50 min versus a much shorter recurrence window for a repetition period of 40 min. In the evening after 6 p.m., the H-Fat recurrence pattern resumes and later converges with a delayed 50-min repetition with the L-Fat group.

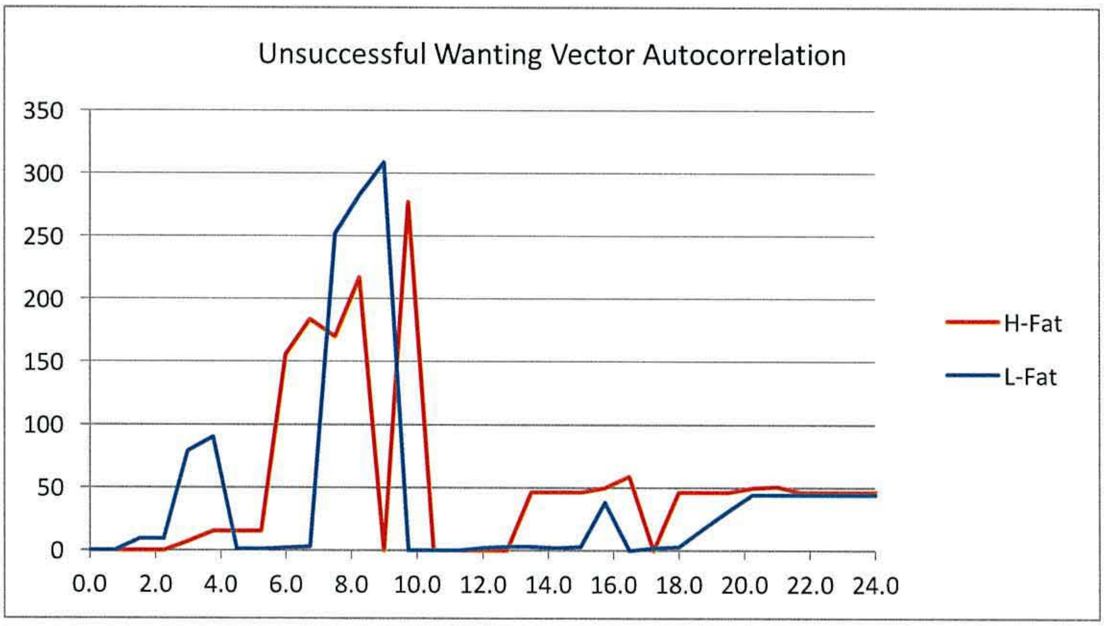

Figure 3.16. Mode periodicity in unsuccessful 'wanting' scores for L-Fat and H-Fat sets.

Case independent W vectors. Autocorrelation, mode tracking, and window lag correction were similarly performed independently on the W vectors for both H-Fat and L-Fat sets. We have superposed two independent plots in Figure 17.

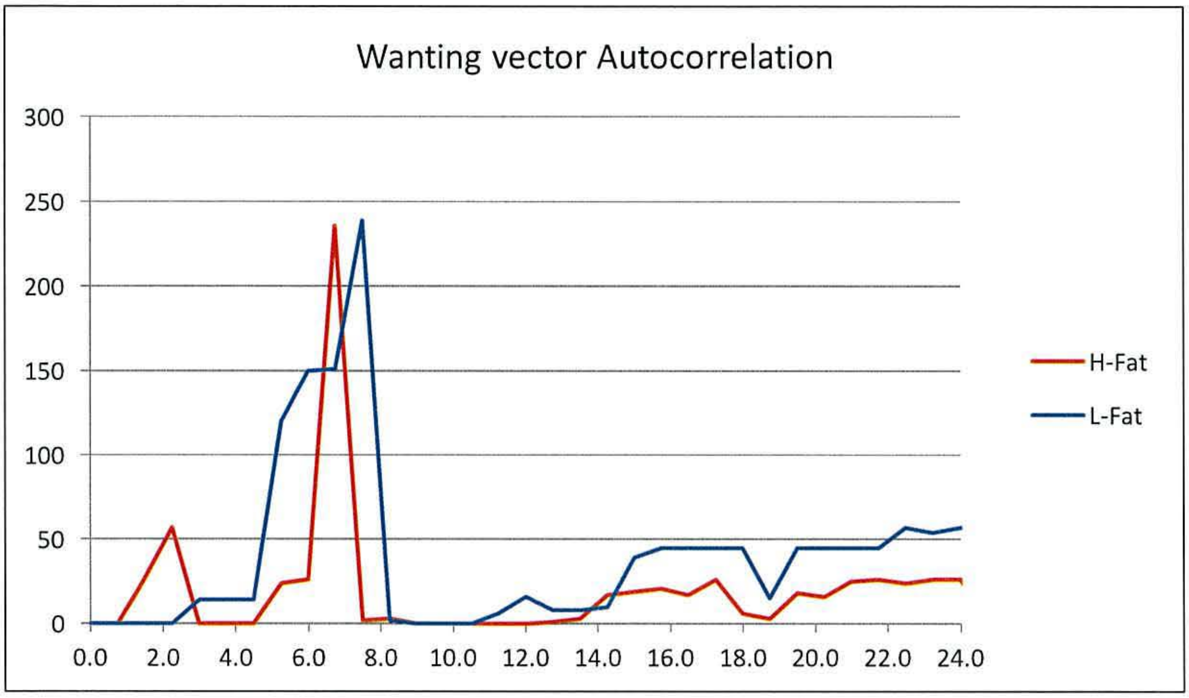

Figure 3.17. Mode periodicity in 'wanting' scores for L-Fat and H-Fat sets.

Over time, the mode periodicities for L-Fat versus H-Fat follow a similar pattern; however, the differences are as follows:

- The early morning L-Fat group periodicity of 240 min is sustained 3 times longer than that of the H-Fat group.
- From 9 a.m. to 6 p.m., the L-Fat group sustains a recurring eating pattern over a period twice that of the H-Fat group.

The W vector recurrence relationships prove to be very similar for both the H-Fat and L-Fat data sets. The distinction is a longer duration of eating period associated with the W vector that occurs between 6 a.m. to 8 a.m. In both data sets, the repetition intervals approach 240 min. The repetition patterns are almost synchronous starting after 2:00 p.m. However, the repetition interval for the L-Fat set is double that of the H-Fat set.

Case independent L vectors. Autocorrelation, mode tracking, and window lag correction were similarly performed independently for the L vectors for both L-Fat and H-Fat sets. We have superposed two independent plots in Figure 3.18.

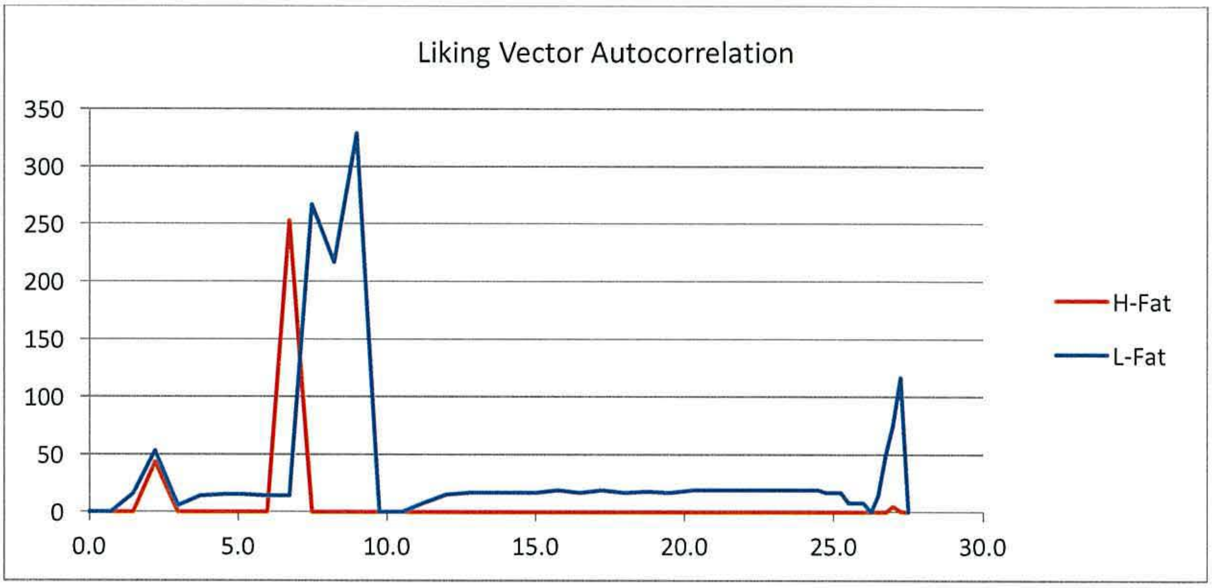

Figure 3.18. Mode periodicity in 'liking' scores for L-Fat and H-Fat sets.

During the early morning hours, the 'liking' scores for the L-Fat and H-Fat sets follow a nearly identical sequence. After 6 a.m., however, the H-Fat repetition period drops entirely for 2 hr, whereas the L-Fat repetition interval sustains a pattern ranging from 250 to 330 min for 2 hr. From 8 a.m. till 9 p.m., the L-Fat group sustains a constant repetition interval of 20 min, whereas the H-Fat group sustains no characteristic period. Comparison of the L vector provides the most distinctive difference between the H-Fat and L-Fat sets, compared to the other data vectors. For the H-Fat set, the duration of repeated 'liking' is significantly shorter than for the L-Fat set. Probably of greatest significance is the non-existence of a regular repetition of 'liking' among H-Fat participants. In contrast, 'liking' with a repetition interval of 20 min is sustained throughout the rest of the day for the L-Fat group.

3.5 Discussion

The application validity

The first question in relation to our smartphone data collection is certainly, whether it reflects participants' real free-living eating behaviour sufficiently, or whether the method suffers from underreporting as seen in diet diaries (Heitmann & Lissner, 1995). Based on the data derived from the phone application, there were small but significant differences in the number of their recorded *wanting* and *successful wanting* events with H-group recording less than L-group, but no difference in *unsuccessful wanting*. Indeed, the number of *successful wanting* events, which is the number of eating events recorded per day (4.33 (1.26) for L-group), is comparable to the 4.8 (1.3) eating occasions per day reported in a study with a much larger group size (n=2385) in free-living conditions (Aljuraiban et al., 2015). Furthermore, similar to our study finding lower eating frequency in the H-group, an inverse relationship between BMI and eating frequency was reported in the same study with other studies confirming this relationship (Mesas, Muñoz-Pareja, López-García, & Rodríguez-Artalejo, 2011a). The quality of our phone application data is further supported by the finding that 30% of all wanting events were resisted, which is in agreement with reports by Massey and Hill (2012), who found that about 70% of cravings led to eating in free-living conditions in dieters and non-dieters. Additionally, our findings show a meal duration of ~17 min, which was not significantly different in the two groups, which is in accordance with earlier reports of meal durations of 16 to 22 minutes depending on meal size (Spiegel, Kaplan, Tomassini, & Stellar, 1993).

In summary, we found that our core data relating to the eating events recorded via the phone application is reflected in the literature and we therefore considered our data suitable for further investigation into associations with measured physiological and psychological characteristics. We considered these associations in the context of the main theories on the causes of overeating. These are mostly mechanistically connected to alterations in the dopamine system in reward relevant areas of the brain in obese people and animal models of overeating (P. M. Johnson & Kenny, 2010; Wang, Volkow, Logan, Pappas, Wong, Zhu, Netusll, & Fowler, 2001a). However, depending on the paradigms used and assessment techniques, increased reward sensitization (Davis, Strachan, & Berkson, 2004b), increased reward anticipation (Pelchat et al., 2004), consummatory reward deficiency (Blum, Gardner, Oscar-Berman, & Gold, 2012), or an impaired prediction and learning of food reward values (Berridge, 2012a; Zhang, Manson, Schiller, & Levy, 2014a) are proposed as important mechanisms in overeating. In particular, it is suggested by the incentive salience hypothesis that anticipatory and consummatory reward systems function in tandem but that, via overpresentation of food stimuli, anticipatory reward response increases while hedonic consummatory reward response is reduced; changes, which are supposedly mainly driven by alterations in the dopamine system (Stice, Spoor, Ng, & Zald, 2009c).

Frequency of Food Wanting and Eating Events

An interesting finding of this study was that the H-Fat group wanted food less often and also reported eating less often compared to the L-Fat group. Many previous studies have explored the association between eating frequency and adiposity measures, but the results were inconclusive and the role of eating frequency in obesity development has been widely debated. While some authors recorded inverse associations between eating frequency and BMI (Holmbäck, Ericson, Gullberg, & Wirfält, 2010; Ma et al., 2002), other studies suggested null or positive associations (Berg et al., 2009; Mills, Perry, &

Reicks, 2011; Yannakoulia, Melistas, Solomou, & Yiannakouris, 2007). A study by Titan et al. (2001) showed that in both men and women, concentrations of total cholesterol and low density lipoprotein cholesterol are negatively associated with the frequency of eating; therefore, their concentrations decrease with an increase in daily eating frequency. Another study also concluded that the increase in eating frequency results in lower body fatness in middle-aged men (Ruidavets, Bongard, Bataille, Gourdy, & Ferrières, 2002). In contrast, higher eating frequency was a significant predictor of increased body fatness in postmenopausal women (Yannakoulia et al., 2007). This, however, was not observed in premenopausal women who took part in the same study.

Literature has also suggested that eating frequency is just one of many factors influencing weight gain. It is now widely recognised that the traditional view of 'eat less, move more' is too simplistic and that there are other biological and sociological factors contributing to weight gain (Chaput, Prud'homme, & Sharma, 2014). Ma et al. (2002) described how an individual's eating pattern constitutes of: eating frequency, the temporal distribution of eating events across the day, meal skipping, and the frequency of eating meals away from home. All these dimensions might relate to obesity development, with eating frequency representing just one component of a person's eating pattern, which should be considered as a whole if we want to better understand the growing obesity epidemic among the general population. Findings by Ma et al. (2002) indicated that while a greater number of eating episodes was associated with a lower risk of obesity, the habit of skipping breakfast presented an increased risk of obesity. This was also found in a Swedish study by Berg et al. (2009), who proposed that food frequency might give us less information on obesogenic food patterns compared to information on portion sizes and meal patterns.

Higher eating frequency has also been linked to higher fibre intake and lower consumption of alcohol and dietary fat, as well as to higher levels of leisure-time physical activity. Therefore, eating more frequently could constitute an overall healthier lifestyle as described in a study by Holmbäck et al. (2010). This could explain our finding of L-Fat participants reporting a higher frequency of eating compared to H-Fat participants. Mills, Perry and Reicks (2011) also emphasised that an individual's total energy intake rather than just eating frequency might be important in obesity prevention. It is possible that the

H-Fat group ate less often, but their food choices and meal sizes might have been obesogenic.

Another possibility to consider is that the finding of lower 'wanting' and eating frequencies in H-Fat participants could be due to inconsistencies between the reported intake and the actual intake. Underreporting has been widely recognised in research on obesity (Finlayson & Dalton, 2012; Raymond et al., 2011; Westerterp & Goris, 2002) and could be explained by personal and societal factors. In a study by Black et al. (1993), obese and previously obese women reported food intake that was only 73% and 64% of their energy expenditure, respectively. These findings need to be viewed in the context of a society that is highly critical of overweight people. Underreporting could be done intentionally in order to improve one's presentation to others (Muhlheim, Allison, Heshka, & Heymsfield, 1998). By reporting food intake that is perceived as socially acceptable, obese people might be pandering to social expectations and creating an image of themselves that is more likely going to be accepted and respected by their peers. Reporting real intake could expose them to criticism, judgment and rejection, which is a situation that people naturally want to prevent and avoid.

In studies that rely on self-reporting, underreporting is a serious methodological problem that needs to be acknowledged (Murakami & Livingstone, 2014). It has previously been asserted that underreporters need to be excluded from the study, or the findings could be deemed erroneous (Fassett, Robertson, Geraghty, Ball, & Coombes, 2007). Furthermore, ideally, all dietary studies would benefit from including independent measures of food intake that would not be subjected to misreporting (Black et al., 1993). For this study, we are not able to conclusively determine whether there were cases of misreporting. However, underreporting would suggest that H-Fat participants underreported on two dimensions—'wanting' and eating frequency—which is somewhat less plausible. Moreover, they would have needed to manipulate the duration of meals (the time distance between 'wanting' and 'liking'). Therefore, manipulations would be difficult to achieve and would lead presumably simply to a reduced report of events (frequency) but not additionally to an influence on scores and meal durations. Our clearer outcomes are indeed on the level of scores rather than on frequency.

Food Cravings and Frequency of Wanting and Eating in High Fat

Participants

Another surprising finding was that although H-Fat participants reported 'wanting' and eating food less often than L-Fat participants, they also reported having more cravings as recorded on the Food Cravings Questionnaire – Trait (FCQ-T). Eating behaviours recorded in real time using a mobile phone application therefore did not correspond with the participants' accounts of their everyday cravings. These two findings present a discrepancy that is worth exploring further.

The Food Cravings Questionnaire is a valid and reliable instrument and is one of the most commonly used instruments for assessing cravings (Meule, Hermann, & Kübler, 2014). Thus, the results of the Food Cravings Questionnaire can be considered accurate, and the explanation for the aforementioned data discrepancy should most likely be sought in other internal and external factors and in putative contributors to behaviours and choices of overweight and obese people.

It could be that obese people answered the questions on the questionnaire according to the image they have of themselves. People around us and in society as a whole are constantly giving us implicit and explicit messages that we gradually integrate into our social image and self-image during the process of socialisation. There are deeply rooted social prejudices and (mis)conceptions connected to the phenomenon of body weight and body image. In the present social milieu, obesity holds an overall negative image and often results in poor self-image and lower self-esteem (Chang, Liou, Sheu, & Chen, 2004). However, the ideas of beauty and social desirability change with time and place. Also, studies have shown that overweight people belonging to some racial and ethnic groups, e.g., African Americans, maintain a more positive self-image of themselves compared to members of other ethnic groups, which could also be related to their family socialisation processes (Granberg, Simons, & Simons, 2009).

The research and practice in the field of obesity is prone to many preconceived ideas and biases. According to the established social narrative and some scientific studies, obese and overweight people are generally expected to have more unhealthy cravings and to eat more (Chaput, Prud'homme, & Sharma, 2014; Scharmüller, Übel, Ebner, & Schienle, 2012). The study's participants could therefore intentionally or unintentionally complete the questionnaires to reflect the socially prevalent image of increased frequency of craving in obese people. It might be difficult to distinguish between the authentic experiences and feelings of H-Fat participants and their reactions to the messages they have been receiving and internalising about themselves and their eating habits over a long period of time. Food cravings are not something specific to obese people and are not inherently pathological (Kemps & Tiggemann, 2010). For example, a study that examined the sugar intake of Malaysians showed that lean people had more cravings for sweet foods and ate more of it compared to obese people (Sia et al., 2013). Nonetheless, many myths and misconceptions about obesity persist in social media, popular culture and also in the scientific literature (Chaput et al., 2014; Mela, 2006), which could influence the participants' responses.

Another explanation for the noted discrepancy could be that when using the Mind Eating application, the participants were building a socially desirable image of themselves by eating less often in an attempt to lose weight. However, when completing the questionnaire, they may have been reflecting their social image of obese people, who tend to crave more food. Misperceptions of obese people regarding their weight have previously been recorded (Duncan et al., 2011; Niu, Seo, & Lohrmann, 2014). Also, perceptions of bodyweight appear to influence food choices and nutritional intake and can negatively influence an individual's attempts to lose weight (Lim et al., 2014; Niu, Seo, & Lohrmann, 2014). Little, however, has been written to date on misperceptions connected with food intake and craving impulses. It could be that H-Fat participants reported their food intake and desires as they perceived them, but these might not match the objective reality of their eating patterns.

Further studies would be required to fully understand the discrepancy in findings and to further explore the underlying psychological and social mechanisms. Our study's findings highlight how the experience of being overweight or obese is imbued with deep psychological and social complexities and might be linked to multiple identities that are constantly being negotiated and managed within the context of a person's life and culture.

Eating and Resisting Frequencies

Food resisting events were found to be essentially equivalent in the H-Fat and L-Fat groups. Resisting strong desires to eat and avoiding overeating has been recognised as a challenge in most weight management strategies (Moffitt, Brinkworth, Noakes, & Mohr, 2012). H-Fat participants in this study were essentially as successful as their L-Fat peers in resisting food.

However, resisting temptation is not necessarily a positive characteristic of a person's eating pattern. Previous studies showed that participants eat more snacks after a period of abstinence from a snack they were exposed to but were not allowed to eat (Soetens, Braet, Van Vlierberghe, & Roets, 2008). Initial resisting can therefore lead to subsequent overeating, which has been described in the Goal Conflict Theory of hedonic eating (Stroebe, Papies, & Aarts, 2008). Paradoxically, resisting can lead to overconsumption due to two co-existing goals interfering with each other. We did not determine yet what the H-Fat participants' actions were following the act of food resisting, but we expect that the duration of food intake and/or the number of eating events would be higher after resisted 'wanting' in the H-Fat group. Indeed this eating behaviour is captured in our data and awaits future analysis, which would be relevant information in the study of obesity.

To the author's knowledge, there have been no previous studies comparing food eating and resisting frequencies in L-Fat and H-Fat people, so we are not able to make any comparisons to the existing literature.

Ratings of Food Wanting and Liking

In order to explore the relationship between 'liking' and 'wanting', three types of rating scores were examined: 'wanting' scores where food was resisted (WR), 'wanting' scores leading to eating events (WE), and 'liking' scores after eating events (L). 'Wanting' and 'liking' are linked to the hedonic appetite system and are regulated by the reward circuitry in the brain, involving dopamine and opioid secretion. In a highly obesogenic environment, the hedonic system plays an important role in food intake and can override the homeostatic system, which is an idea relevant to research on eating patterns and obesity (Finlayson & Dalton, 2012; Lowe & Levine, 2005). To better understand the phenomenon of obesity, it is important to distinguish between 'wanting' (the motivation to engage in eating) and 'liking' (the pleasure derived from eating), and the task of separating the two has not been without methodological challenges (Finlayson & Dalton, 2012; Mela, 2006). There is a recognised interaction between 'wanting' and 'liking', and one without the other does not bring a satisfactory and fulfilling experience (Finlayson, King, & Blundell, 2007). It has also been asserted that when 'wanting' and 'liking' become enhanced or dissociated, this can lead to certain eating disorders (Finlayson & Dalton, 2012). It also needs to be acknowledged that 'liking' and 'wanting' are subjective measurements and their relationship to objective processes in the body is not yet clearly established or understood (Finlayson & Dalton, 2012).

In this study, 'liking' scores were significantly higher than eating scores. This means that participants rated their food reward after consumption to be higher than their anticipatory rating (WE). Although this pattern was observed in the L-Fat and H-Fat groups, only in the L-Fat group was the differentiation statistically significant. Furthermore, compared with H-Fat participants, L-Fat participants had higher 'liking' scores following a meal. This suggests that the H-Fat group experienced a smaller reward from eating and their perceived gain was not as high as for L-Fat participants. Previous studies asserted that overweight and obese people generally have higher 'wanting' than lean individuals and are willing to work harder for their snacks, especially for high-calorie snacks (Epstein et al., 2007; Giesen, Havermans, Douven, Tekelenburg, & Jansen, 2010; Mela, 2006; Saelens & Epstein, 1996). At the same time, obese people generally exhibit lower 'liking' compared to their normal-weight peers, which was also found in the present study. The dissociation of 'wanting' and 'liking' is seen as a problematic feature of eating patterns observed in obese individuals. This is described by the incentive salience theory, which suggests that obese people expect more reward from food than what they experience (Berridge, 2009). When a reward is smaller than anticipated by the person, this can lead to an unhealthy experience and an imbalanced response. Moreover, a past review of studies that were based on laboratory tests showed that obese people have a greater motivation to consume energy-dense foods and that they derive greater 'liking' from consuming foods high in fat, which may be associated with the development of obesity in this population (Mela, 2006).

Two scientific theories have been proposed to explain the finding of lower 'liking' in obese and overweight participants, and they both explore the role of brain reward mechanisms in eating patterns. While some authors believe that obese people suffer from a reward deficiency syndrome (Davis & Fox, 2008; Pagoto, Spring, Cook, McChargue, & Schneider, 2006; Wang et al., 2002), others support the theory of a heightened sensitivity to rewards (Davis et al., 2007; Davis & Woodside, 2002; Franken & Muris, 2005).

Reward deficiency syndrome (RDS) has been associated with hypo-dopaminergic functioning of the brain that could arguably be gene-based (Blum et al., 2012). According to this theory, individuals seek food that would enhance their dopamine activation and improve their mood (Blum & Braverman, 2001). In an under-active reward pathway, food acts as a dopamine simulator; its function is similar to that of an addictive substance (Bowirrat & Oscar-Berman, 2005). The food therefore does not produce the expected experience of postprandial pleasure and satisfaction, but serves to fix the chemical deficiency, which needs to be regulated on an ongoing basis. Studies also showed that obese people are less likely to choose other, more functional, alternative behaviours that could replace unhealthy eating (Finlayson & Dalton, 2012). It is not clear yet whether lower dopamine levels in the brain are genetically inherited or are a result of environmental factors such as stress or substance abuse (Davis & Fox, 2008). However, some authors emphasise that, since the obesity epidemic developed only in the last few decades, it cannot be attributed to a change in the genome (Small, 2009).

The other hypothesis suggests that some individuals have a heightened reactivity to reward impulses, which can be combined with a diminished ability to inhibit the impulses on a cognitive level. The inability to control these increased impulses predisposes individuals to overeating, and is a mechanism that has also been recognised in compulsive drug use (Nederkoorn, Smulders, Havermans, Roefs, & Jansen, 2006). In relation to eating behaviour, it is possible that some characteristics of the modern environment - such as constant food advertising and availability of reward cues –could contribute to non-homeostatic eating due to the increased inability to resist these impulses. A meta-analysis by Boyland and colleagues (2016) suggested that acute exposure to food advertising increases food consumption in children. However, adult's food intake has not been linked to modern advertising techniques (Boyland et al., 2016).

It has also been suggested that although the two mechanisms—hypofunctioning reward circuit and heightened cue-reactivity—seem to be at odds, they can in fact co-exist and, in many instances, hypo- and hyperactive responses happen at the same time (Small, 2009).

Meal duration did not differ significantly between the L-fat and H-fat groups. Meal duration has previously been explored in connection with obesity and different factors that contribute to meal length have been identified (Stroebele & de Castro, 2006; Zhu & Hollis, 2014). Different forms of distraction can influence energy intake. For instance, Ogden et al. (2013) found that participants who watched TV whilst eating ate significantly more compared to those who ate alone or ate while driving or interacting with others. Generally, eating slowly has been linked to decreased risk of obesity and people have been encouraged to chew more in order to prolong their meals (Zhu & Hollis, 2014). This study, however, did not provide evidence for the connection between meal duration and weight management.

Implicit and Explicit Attitude Scores.

It has previously been suggested that disinhibited eating correlates with both explicit and implicit food attitudes, and that binge eating has specifically been connected to implicit attitudes (Czyzewska & Graham, 2009; Goldstein et al., 2014). At the same time, there have not been many studies that explored food attitudes.

In this study, implicit attitude scores did not differ between the groups, however, explicit attitude scores were significantly higher in the L-Fat group than in the H-Fat group. Some previous studies showed no differences in explicit food attitudes in lean and obese participants (Craeynest et al., 2005; Roefs & Jansen, 2002). This study did not use the somewhat traditional obese/lean differentiation, which could have influenced the finding that L-Fat people record a more positive attitude towards healthy food.

Obese people were previously found to have a more negative implicit attitude towards high-fat food. This was initially an unexpected finding, but was later explained by the deeply engrained social connotations of high-fat and low-fat foods (Roefs & Jansen, 2002). It appears that implicit attitudes might not help to explain a person's unhealthy behaviours. On the other hand, a study by Craeynest et al. (2005), which included children and adolescents and assessed their attitudes towards food and physical activity, revealed that obese children had more positive implicit attitudes to both healthy and unhealthy food compared to lean controls. This suggests that obese children prefer to eat more regardless of food characteristics, which would explain their higher weight status.

Furthermore, a study of attitudes towards chocolate suggested that a discrepancy between implicit and explicit attitudes predicted chocolate consumption and might be linked to overeating (Goldstein et al., 2014). However, the correlation between implicit and explicit attitudes has not been explored herein.

Obesity studies usually include and compare obese and lean participants, who are at the extremes of the distribution pattern. This study, however, also included those who are found in-between and might be at risk of developing obesity. Not much is known about the characteristics and eating patterns of these individuals, but their inclusion could explain why some of the study's findings did not correspond with the existing literature in this field. Therefore, a stronger knowledge base of pre-obese people is required to increase the understanding of individuals who are at risk of becoming obese, and to develop more successful intervention methods that could address their eating preferences and patterns before these behaviours result in morbidity.

There is a need for further studies that would replicate and expand on the current study, as well as provide better insights into different groups of people, their attitudes, preferences and thoughts connected with food intake.

Time Series Discussion

Analysing the timings and patterns of eating behaviour using classical statistical methods (e.g. correlation) often does not result in a meaningful data analysis, especially when presented with dynamical data that have a natural temporal ordering and/or a special internal structure that should be accounted for. Therefore, such analyses are often disregarded (Madsen, 2007).. .

To the best of our knowledge, this study was the first to use time series methodology to analyse the "wanting" and liking" components that guide eating behaviour. In time series research design, each participant or sample is observed multiple times and its performance is compared to its own previous performance. This approach allows for a deeper understanding of the patterns of eating behaviour in which there is no natural ordering of the observations (Lin et al., 2003). Special statistical methods are used with the time series approach to analyze and model an ordered sequence of observations. In the applied literature, these observations are sometimes called signals (Madsen, 2007). Time series are used in different fields of research and investigation, such as control engineering, astronomy, earthquake prediction, communications, the stock market, and applied sciences that require temporal measurements or measurements of irregular or non-stationary components (Coco & Dale, 2014; Ivanov & Rosenblum, 1996).

Since in this study smartphones were used to collect data, time series approach was facilitated by the use of modern digital technology. Data from the Mind Eating application was analysed using time series methods such as stochastic analysis and autocorrelation. Autocorrelation describes the association between values of a process at different times as a function of two times or of a time lag. In summary , it is a mathematical tool to find the similarities between observations of time and repeated patterns (Dunn, 2014).

In our study, we developed a MATLAB algorithm to group all the individuals' data in sequence. VB.NET was another application that was developed to perform the four levels of decomposition and analysis. MATLAB averaged parameters (eating, wanting, liking) were represented for every minute of the day; the average was taken over 30 minutes and this window was moved in 1 minute steps along the series for all individuals together over 14 days. These composite values were fed sequentially into the time pattern analysis tool, which revealed deeper and more insightful results compared to the classical statistical methods.

The H-Fat individuals' pattern of unsuccessful wanting fluctuated sharply during the day and was changing, between maximum and minimum scores within a short time period (see Figure 13.16). In contrast, the L-Fat individuals' pattern was consistent during the day and hit the top score twice, before lunch time and dinner time. These results show that wanting was often resisted in both groups of individuals. However, the successful wanting scores of H-Fat individuals were generally lower than those of L-Fat individuals for most of the day (Figure 13.17). Thus, H-Fat individuals most likely ate with successful wanting scores lower than their unsuccessful wanting scores in the same periods.

Previous studies showed that prohibition and resisting temptation do not necessary result in positive behaviour change (De Witt Huberts, Evens, & de Ridder, 2013; Shmueli & Prochaska, 2009; Soetens, Braet, Van Vlierberghe, & Roets, 2008). A study by Soetens and colleagues (2008) which exposed some of the participants to a forbidden snack for 24 hours revealed that prohibition along with exposure can sometimes backfire and increase the risk of losing control over eating. This behaviour was especially significant in women who were at high risk of disinhibited restrained eating (Soetens, et al., 2008).

During the day, individuals in the L-Fat group generally had higher successful wanting scores compared to the H-Fat group; except in the early mornings possibly due to people being habitually prone to eat food at the start of the day. The role of breakfast in weight management has been extensively discussed, and breakfast consumption and type of breakfast have been linked to BMI values (Ashwell & Hunty, 2012; Klimesova, Miklankova, Stelzer, & Ernest, 2016; Leidy, Hoertel, Douglas, Higgins, & Shafer, 2015; Vander, Gupta, Khosla, & Dhurandhar, 2008). The finding of this study that H-fat participants experienced more wanting and eating during the breakfast hours is surprising and adds an interesting new dimension to the ongoing debate on the causes of obesity. Some previous studies found that skipping breakfast can be correlated to obesity (Watanabe et al., 2014), however , this is not a uniform observation. A systematic review by Mesas et al. (2012) found that there was inconsistent evidence of a relationship between skipping breakfast and excess weight (Mesas et al 2012).

Individuals in the H-Fat group also had lower liking scores compared to the L-Fat group for most of the day except, again, in the early morning. Therefore, morning is the only period when H-Fat individuals had higher scores for all three parameters: unsuccessful wanting, successful wanting, and liking. For the remainder of the day, liking scores for the H-Fat group were lower until late at night, when the liking scores increased again.

It is worth noticing that eating scores (successful wanting scores) for lean people in the L-Fat group were almost not exist late at night. This indicates that this population has less eating events late at night. In contrast, eating scores for the H-Fat group were higher late at night and were associated with very low liking scores (Figures 3.17 and 3.18). Research has shown that meal time plays an essential role in weight gain and appetite (Arble, Bass, Laposky, Vitaterna, & Turek, 2009; Fonken et al., 2010; Wu et al., 2011). Many studies found that skipping an early morning meal and overconsuming late in the evening has crucial implications for weight gain and obesity (de Castro, 2007; Leidy & Racki, 2010). Watanabe et al. (2014) found that individuals who ate dinner less than three hours before going to bed, had higher BMI and waist circumference compared to those who ate more than three hours before bedtime. Moreover, the observation that the H-fat group had a delay of approximately one hour in peak evening eating time, might also contribute to the growing body of knowledge on the significance of overnight fasting period. Gill and Panda (2015) found that when overweight individuals ate for only 10 to 11 hours daily and had a longer fasting period, their weight reduced over a period of 16 weeks.

The sequence of periodicity was computed separately for each group and plotted together for further investigation in the autocorrelation analysis. The results show a similar periodicity for the morning events for both groups in all components of unsuccessful and successful (eating) wanting and liking (Figures 3.16, 3.17, and 3.18). Interestingly, this similarity was maintained for both groups in unsuccessful and successful wanting, but not in liking. In the liking plot of periodicity (Figure 24), the vector of the L-Fat group remained constant for the rest of the day following a morning meal. This is in contrast to the H-Fat group in which there is no liking periodicity detected for the rest of the day. The timing of the morning meal is obvious in all plots of periodicity (Figures 3.16, 3.17, and 3.18). This could be explained by considering the daily rhythm, which for all individuals began in the morning. However, events that followed later in the day most likely varied between individuals and reflected their individual choices, characteristics and personal circumstances.

Another possible explanation for the disappearance of periodicity in liking -but not in wanting -in H-Fat individuals could suggest that wanting and liking are not linked or coupled in this population. This could imply that reward processing in the brain of obese people differs from that of lean people, and it is possible that it is dysfunctional. Periodicity might have helped to disintegrate the signal and describe the components in an unsophisticated way. iIf we had found periodicity in both components (wanting and liking), then we could have assumed that the system is connected and contains coupled components. Already Berridge et al. (2010) proposed that wanting can exist as a separate entity. Berrdige and Valenstein (1991) also showed that wanting can get enhanced without liking. It is therefore possible that obese people crave food without liking or reward. In contrast, periodicity for both wanting and liking was observed in lean individuals, which implies there are perceptual differences between the two groups.. The time series and pattern results fit very well with our previous aggregate data, where the results for liking (reward) were always different in H-Fat individuals and, altogether, suggest a deficiency in the reward mechanisms of overweight/obese individuals.

3.6 Limitations :

Certainly, our data collection has many limitations based on the fact that we have no distinct experimental paradigm and therefore the conditions, in which participants use the phone application, vary dramatically and compliance with the experimental protocol might have varied as well. Otherwise, in our view, it is remarkable how robustly our free-living recordings point toward distinct alterations in wanting and liking perceptions towards food in obese people as suggested by the main theories in eating disorders

3.7 Conclusion:

In summary, our data collected in free-living condition with a novel smart phone application could be interpreted as giving strong support for reward deficiency in obese people while several observations point towards a more complex problem with involvement of an enhanced contribution of craving to wanting, and a failure to integrate former consummatory reward information into the reward expectation. In particular, these findings are of high value to the further investigation of related hypotheses in more stringent experimental conditions.

CHAPTER 4

4. STUDY 3: PILOT STUDY: EFFECT OF SINGLE BOUT OF EXERCISE ON 'WANTING' AND 'LIKING" OF FOOD AND DRINK

4.1 Introduction

Exercise for Weight Loss

Dieticians/nutritionalists treating obesity will often recommend physical exercise to their patients to help them lose weight and to prevent further weight gain (Donnelly et al., 2009). This additional exercise can affect the energy balance of the body so that more energy is expended than is taken in (Donnelly, 2004). Energy intake is the energy added to the body from the consumption of food and drink. Energy expenditure is the energy lost from the body during physical activity and from metabolic processes such as maintaining homeostasis (the resting metabolic rate) and digesting food (the thermic effect of food) (Ravussin & Bogardus, 1992). Exercise increases energy expenditure through the physical work of the activity itself and, indirectly, by elevating the resting metabolic rate (Votruba et al., 2000). Thus, individuals can lose weight when their energy expenditure exceeds their energy intake, i.e. when their energy balance is negative.

Exercise can also facilitate weight loss by inducing appetite suppression (i.e. by exercise induced anorexia). For example, King et al. (1994) found that exercise suppressed the hunger of lean subjects and delayed the onset of their next meal. These effects were associated with the suppression of appetite-inducing hormones following exercise (Martins et al., 2007). Therefore, the two effects of exercise – creating a negative energy balance and suppressing appetite – demonstrate the potential of exercise to increase weight loss in obese and overweight individuals.

Despite this hypothesis, studies on the effects of exercise on weight loss and obesity have shown variable outcomes. For example, a meta-analysis by Epstein and Wing (1980) found that individuals lost a smaller amount of weight through aerobic exercise than was predicted. Similarly, Donnelly et al. (2004) found that exercise alone was not an effective method for weight loss, though it could improve various health parameters. Finally, Hopkins et al. (2010) reviewed numerous studies and found that both acute and long-term exercise had inconsistent effects on weight loss.

One explanation for these variable outcomes of exercise on weight loss may be that a negative energy balance in the body is the cause of compensatory eating behaviours (Stubbs et al., 2004). For example, King et al. (2008) found that exercise-induced weight loss over a 12-week study period was less than predicted because individuals varied their eating behaviours to compensate for the energy deficit created by exercise. King et al. (2012) and Hopkins et al. (2013) have also found that the energy expenditure during exercise was compensated for by variations in post-exercise eating behaviour.

Causes of Eating Behaviour

Eating behaviour is controlled by a combination of both homeostatic and hedonic factors. Homeostatic eating behaviour allows the body to maintain itself in a constant state with the energy and nutrients it needs. In contrast, hedonistic eating behaviour rewards the body with the pleasure of 'liking' and 'wanting' food and drink (Saper et al., 2002; Mela, 2006). 'Liking' refers to the immediate sensory experiences from consumption, such as satiety, palatability and taste. These experiences are important for successfully restraining diet after exercise (Born et al., 2011). 'Wanting' refers to the motivational qualities that make food or drink stand out as attractive and desirable stimuli, i.e. their incentive salience (Berridge et al., 2009). Incentive salience includes the psychological reward of satisfying physiological hunger, along with other genetic or learned neuropsychological qualities such as taste perception, food preference, cognitive expectation, reward attractiveness and reward sensitivity. In addition, these hedonistic motivations for food and drink are often triggered by social and environmental cues (Berridge et al., 2010).

Overall eating behaviour is predicted strongly by the hedonistic reward value of food (Borne et al., 2010). However, in some individuals, the hedonistic eating response for 'liking' and 'wanting' could not only act independently of the homeostatic one, but could override it completely (Finlayson et al., 2008a). This decoupling of energy intake and expenditure (Mela, 2006) may be caused by distortions in the reward mechanisms of the brain, resulting in various eating disorders such as obesity (Berridge et al., 2010).

Finlayson et al. (2009) concluded that some individuals are [genetically or environmentally] predisposed to over-compensating their eating behaviour following exercise (Finlayson et al., 2008b; King et al., 2012). For example, in a 6-week exercise intervention study, Martins et al. (2008) found that, although (physiological) appetite was suppressed following exercise, lean individuals were more sensitive to homeostatic drivers of eating behaviour than were overweight/obese ones. Thus, overconsumption caused by a hedonistic response overriding a homeostatic one (Harold et al., 2012) could explain the variability in weight loss in these studies (King et al., 2013). Therefore, Finlayson et al. (2009) recommended that hedonistic eating behaviour should be considered as a relevant factor in future exercise interventions in weight loss and obesity.

Criticism of the Literature

In previous exercise intervention studies, variations in eating behaviour have caused different weight loss outcomes. Kawano et al. (2013) identified that experiments measuring physiological hunger did not account for the hedonistic response. In addition, questionnaires did not query both physiological and psychological dimensions of eating behaviour. For example, the Food Craving Inventory (FCI) queries only some craving dimensions for different classes of foods (White et al., 2002). Similarly, the Visual Analogue Scale (VAS) fails to query the psychological dimension (Meule et al. 2012). Finally, since eating often occurred on a continuous time scale, studies that measured eating behaviour at fixed time points in relation to exercise (Finlayson et al. 2009) may have failed to capture events that occurred before or after data collection. In summary, these three limitations in the literature surely affected the validity of existing findings and justify the use of new tools that can capture the full effects of exercise on the eating behaviours of different individuals.

Aims

This project aims to study the physiological and psychological dimensions of eating behaviour in order to understand the time patterns, frequencies, and intensities of the hedonistic responses of 'liking' and 'wanting' events measured by different tools. In particular, it aims to compare these events at baseline and post-exercise in sedentary lean and overweight/obese individuals (but not in physically-active or athletic ones). Therefore, the research question is: How does an individual's BMI affect the 'liking' and 'wanting' responses in the 24 hours after exercise?

Hypotheses. The four hypotheses are:

1. Exercise will affect the time pattern, We hypothesized it will decrease scores and frequency of 'liking' and 'wanting' events in both lean and overweight/obese individuals. These effects on eating behaviour will be measured by two tools: a phone application and questionnaires.
2. Post-exercise physiological hunger (i.e. appetite) will be suppressed temporarily in both lean and overweight/obese individuals.
3. The 'liking' scores captured by the phone application of lean individuals will be higher after exercise than at baseline. However, there will be no differences between lean and overweight/obese groups at baseline or between the 'liking' scores of overweight/obese individuals at baseline and after exercise.
4. The 'wanting' scores in the 24 hours following exercise will differ for lean and overweight/obese groups. For overweight/obese individuals, their 'wanting' scores will increase above baseline. For lean individuals, their 'wanting' scores will decrease below baseline.

4.2 Method

Ethical Approval

The ethics board of the School of Sport, Health and Exercise Sciences (SSHES), Bangor University approved the experimental protocol. Both dialogue and information sheets were used to explain these procedures and their potential risks before participants provided written consent to participate in the study.

Participants and Design

Participants were recruited through an advertising campaign in the university and its surrounding areas, using leaflets, posters, emails, and by word of mouth. In addition, participants were advised about eating behaviour change and exercise and were provided with measurements of body composition and cardiovascular fitness as incentives to take part in the study. In total, 19 sedentary individuals (12 male and 7 female) comprised the 8 lean and 10 overweight/obese participants. Please note that the data for one obese participant was excluded from the study due to a phone malfunction in which the data were not recorded.

Participants were given a preliminary screening. This process ensured all participants were:

- 18 to 40 years' old
- free from disease or injury of the lungs, bones, muscles, or metabolism
- living a sedentary lifestyle free of any form of exercise

Participants were then classified as:

- lean (BMI: 18.5-25 kg/m^2) or overweight (BMI: >25 kg/m^2)
- users of Android or iPhone smart phones

The study used a repeated measures crossover design in which the participants received two trials. Participants took the baseline test and were divided randomly into two streams. The first stream took the exercise trial followed by the control trial; the second stream took the same trials in the reverse order. Between each test/trial was a one-week gap (Figure 4.1).

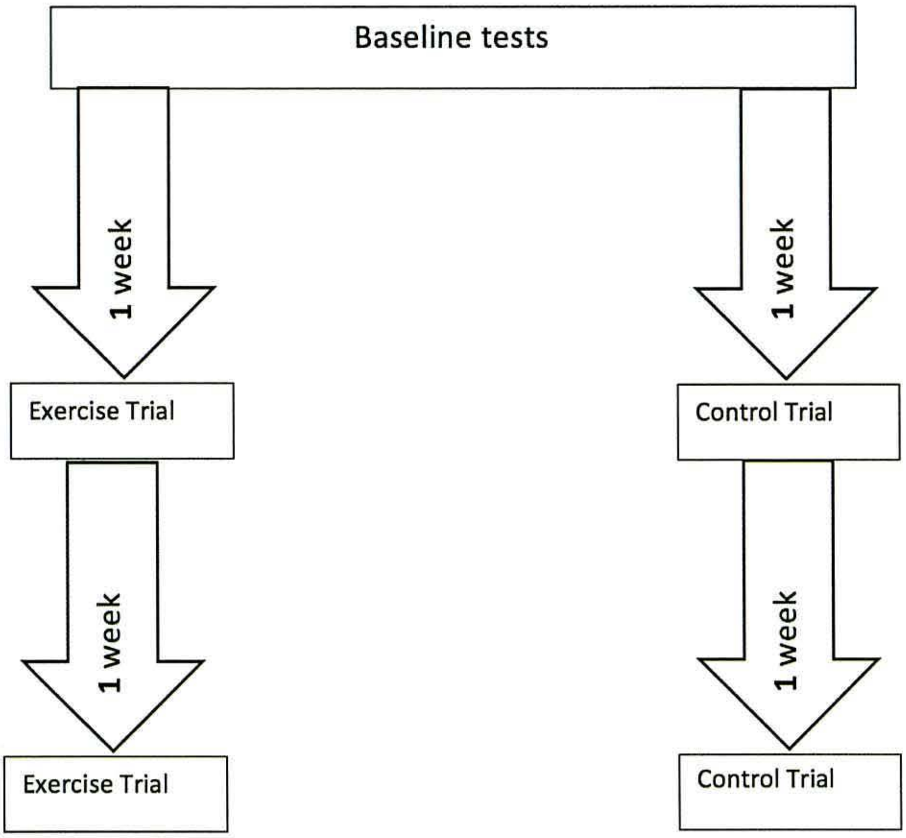

Figure 4.1. A cross-over research design with streams for the control and exercise trials.

Baseline Procedures

Anthropometric measurements. Participants dressed in light-weight clothing without footwear and emptied their pockets. Measurements were then recorded for height (to the nearest 0.1 cm), body mass (to the nearest 0.1 kg), and body composition with a stadiometer (Bodycare Products, Southam, United Kingdom) a balance (Seca, Hamburg, Germany), and a bio-electrical impedance analysis (Inbody 230, Biospace Ltd, California, USA), respectively.

Subjective ratings of appetite. Appetite was rated subjectively using a Food Craving Questionnaire (FCQ). The FCQ is a validated questionnaire (Cepeda-Benito et al., 2001;

Nijs et al., 2007) that differentiates between the physiological and psychological dimensions of eating behaviour and craving (Meule et al., 2012).

Participants answered questions on the FCQ-Trait (FCQ-T) and the FCQ-State (FCQ-S), which are independent of or dependent on physiological or psychological states, respectively.

FCQ-T

Answers to the FCQ-T did not depend on the physiological or psychological state of the participants. Each statement was rated on a 6-point Likert-type scale from 1 (never) to 6 (always) according to how frequently it is true in general.

The questionnaire assessed the following 9 dimensions of food craving:

1. Positive reinforcement - the anticipated positive emotional reward from eating
2. Negative reinforcement - the anticipated relief from negative emotions after eating
3. Feelings of hunger - general feelings of hunger or fullness
4. Intentions to eat - making plans for eating food
5. Cue dependent eating - the triggering of food cravings by environmental cues
6. Negative effect - the effect of negative emotions on food craving or eating
7. Preoccupation with food - thoughts or a preoccupation with food
8. Lack of control - the loss of control over eating before and during eating
9. Guilty feelings - guilt felt for food cravings and/or the lack of control over them

FCQ-S

Answers to the FCQ-S did depend on the physiological or psychological state of the participants. Each statement was rated on a 5-point Likert-type scale from 1 (strongly disagree) to 6 (strongly agree) according to the extent it was true at the time of completing the questionnaire.

The questionnaire assessed the following 5 dimensions of food craving (including sweet and savoury foods):

1. Positive reinforcement - the anticipated positive emotional reward from eating.

2. Negative reinforcement - the anticipated relief from negative emotions after eating
3. Feelings of hunger - physiological feelings of hunger or fullness.
4. Lack of control - the loss of control over eating before and during eating.
5. Intense desire to eat - the intensity of the desire to eat a specific food.

2.3.3 Maximal oxygen consumption

Participants were tested by the modified YMCA sub-maximal exercise protocol (Akalan et al., 2008), which estimated maximal oxygen consumption on an electronically braked cycle ergometer (Corival 400, Lode, Groningen, Netherlands). The protocol consisted of three or four consecutive 4-minute workouts during which participants were given verbal encouragement to maintain a cadence above 50 rpm. In the final 15 seconds of each workout, heart rate and perceived exertion were measured with a Polar FT1 (Polar Electro Oy, Kempele, Finland) and rated on the BORG scale (1970), respectively.

The first workload was set at 25 Watts. Subsequent workloads were then determined for each participant by his heart rate in the final 15 seconds of exercise (If HR <80 bpm: 125 Watts; 80-90 bpm: 100 Watts; 90-100 bpm: 75 Watts; >100bpm: 50 Watts). After every 4 minutes, the workload was continually increased by 25 Watts. Maximum oxygen consumption ($VO_{2\,max}$) was estimated when the heart rate for two workloads was between 110 and 150 bpm. However, the test was discontinued if a participant's steady-state heart rate was within 10 bmp of 85% of the value for his age-predicted heart rate max (i.e. (220 bpm - age).

The phone application. In this study, a novel tool (Mind Eating) application was used that allowed participants to record their own eating behaviours on a mobile phone application. This tool has two advantages over questionnaires. Firstly, it collected data continuously over multiple time points, which ensured all 'liking' and 'wanting' events were captured. Secondly, the app gave insights into patterns of eating behaviour that participants perceived themselves outside of laboratory conditions.

Participants, who were either iPhone or Android users, downloaded the app from the iTunes Store or were sent the app by email. A unique username and password were provided and the participants were trained on how to access the app, to record any 'liking' or 'wanting' events, to note any events they forgot to input, and to correct any errors while inputting the data. The data took only a few seconds to input and was sent for storage in an online database. On completion of the protocol, researchers downloaded the participants' data, analysed it, and corrected any inputting errors.

The app is able to distinguish eating behaviours for both food and drink. However, only the data for food were studied in this research. The app measured the following 7 dimensions in which each 'wanting' event was scored on a scale of 0 (no wanting) to 10 (a very high level of wanting), and each 'liking' event was scored on a scale of 0 ('did not enjoy meal at all') and 10 ('enjoyed meal very much'):

1. Frequency of wanting - the number of 'wanting' events per unit time.
2. Sum of total wanting - the sum of the 'wanting' scores for all 'wanting' events in a unit of time.
3. Meal frequency - the number of 'wanting' events per unit time that led to meal intake.
4. Sum of successful wanting - the sum of wanting scores in a unit of time that led to meal intake.
5. Sum of meal liking - the sum of 'liking' scores for all 'liking' events after meal intake.
6. Sum of meal duration - the sum of the durations of all meals in a unit of time.
7. Resisted wanting - a 'wanting' event where meal intake was resisted. Resisted wanting = (sum of total 'wanting'*frequency of 'wanting') - (sum of successful 'wanting'*meal frequency).

Experimental Procedure

Figure 4.2 shows that participants attended the laboratory for three visits. During the first visit, baseline measurements for height, weight, and body composition were taken followed by an FCQ-T rating and a measurement of $VO_{2\ max}$. During the second visit, participants performed the exercise or control trial (then crossed over to the other trial on the third visit). For both trials, participants were instructed to use the phone app 24 hours before and after attending the laboratory.

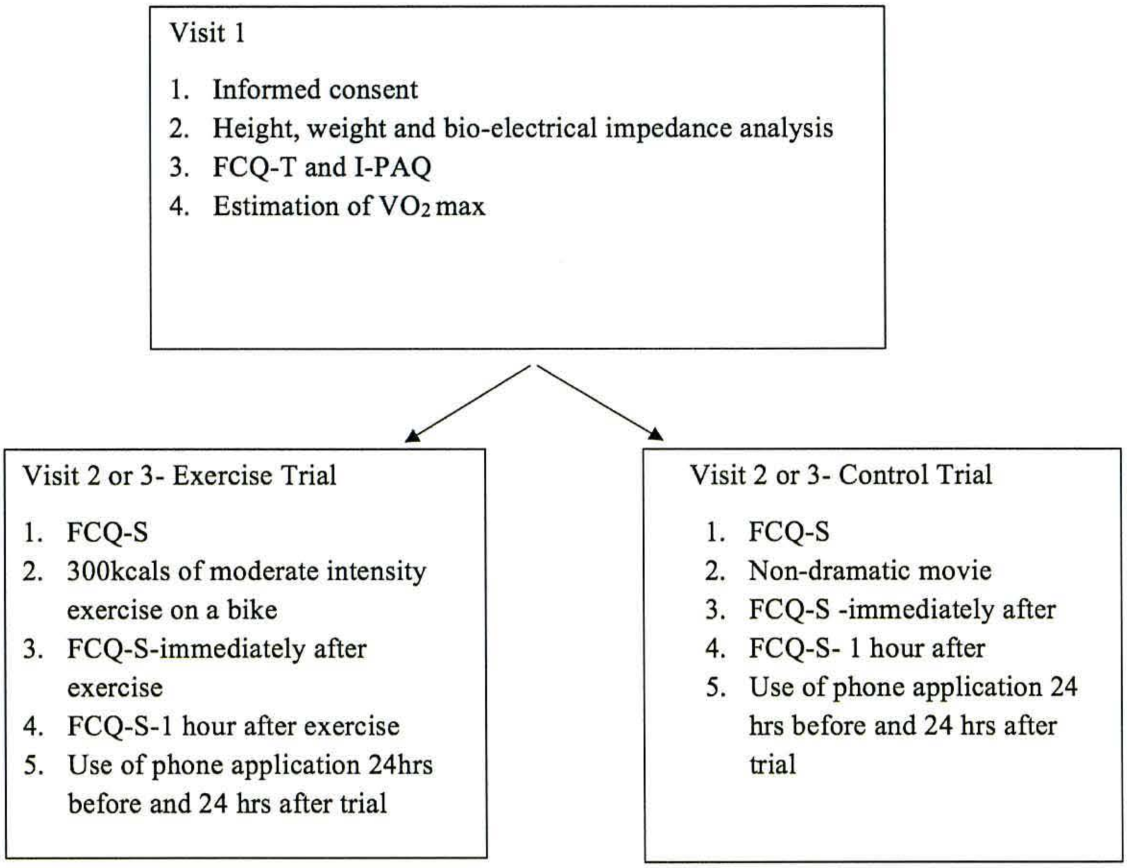

Figure 4.2. The experimental procedure.

For the exercise trial, participants completed an FCQ-S then exercised on a cycle ergometer (Corival 400, Lode, Groningen, Netherlands) for 300 kcals at 70 % of their estimated $VO_{2\ max}$ (HR controlled). For the control trial, participants watched a non-dramatic movie. All other relevant variables were kept identical between the two trials. One hour following the exercise or control trial, a second FCQ-S was completed

Statistical Analysis

The data were analysed by the Statistical Package for Social Science (IBM SPSS Statistics: Version 22, SPSS Inc, Chicago, IL). Relevant assumptions of normality and homogeneity in the covariance matrices (tested by Box's M test) were tested. For non-parametric data, values were either Ln or Log transformed before the analysis.

Phone app data were analysed using a 2 (time) x 2 (group) x 2 (trial) mixed model ANOVA with repeated measures over time. FCQ-T data were analysed by single factor ANOVA and FCQ-S data were analysed by a 3 (time) x 2 (group) x 2 (trial) mixed model ANOVA with repeated measures over time. The relationship between the dimensions in the phone app and FCQ-T and FCQ-S were investigated with a bivariate Spearman's rank correlation. Differences across time and between the exercise and control trials were revealed by Bonferroni's post-hoc tests and independent ANOVAs. Although statistical significance was set at a $p\text{-value} < 0.05$, a $0.05 < p\text{-value} < 0.10$ was, given the small number of data points, considered as indicating "a trend towards statistical significance".

4.3 Results

Baseline Anthropometric Measurements

As expected, baseline measurements for weight, BMI, and body fat are significantly higher in the overweight group than in the lean group (Table 4.1). However, there are no significant differences in the two groups for age or $VO_{2\ max}$.

Table 4-1.

Baseline Anthropometric Measurements for Lean and Overweight Groups.

	Lean	**Overweight**
Age (yrs)	24.75 ± 4.40	25.50 ± 3.22
Height (m)	1.70 ± 0.08	1.75 ± 0.05
Weight (kg)	59.98 ± 11.31	97.74 ±8.33*
Body Mass Index ($kg.m^{-1}$)	20.55 ± 2.15	31.92 ± 3.50*
Body Fat (%)	14.40 ± 1.14	31.20 ± 9.88*
Estimated VO_{2max} ($ml.min^{-1}.kg^{-1}$)	31.94 ± 6.25	30.43 ± 4.98

Values are means ± SD, Lean n=8(males n=2, females n=6), Obese n=10(males n=9, females n=1). * indicates significant differences between the groups.

Subjective Ratings of Appetite – FCQ

Appetite was rated subjectively using the FCQ. Participants answered questions on the FCQ-T during the baseline tests and on the FCQ-S before (Pre), immediately after (Post), and 1 hour after (1Hr) the exercise and control trials.

FCQ-T. Of the 9 dimensions of food craving that are independent of physiological or psychological state, the mean scores for 3 dimensions differ significantly between the lean and overweight groups. Table 4.2 shows these dimensions are: ‘cue dependent eating’

(12.13 ± 3.95 vs 15.20 ± 1.64), ‘lack of control’ (16.13 ± 7.18 vs. 20.90 ± 5.61), and ‘guilty feelings’ (5.63 ± 2.42 vs 8.40 ± 3.90). These 3 mean scores are significantly higher for the overweight group, but no differences are observed for the other 6 dimensions.

Table 4-2.

FCQ-T Scores for Lean and Overweight Groups at Baseline.

	Lean	**Overweight**
Positive Reinforcement	17.00 ± 5.59	14.60 ± 5.11
Negative Reinforcement	8.88 ± 3.74	8.50 ± 3.25
Intentions to Eat	10.50 ± 3.72	10.50 ± 2.80
Cue Dependent Eating	12.13 ± 3.95	15.20 ± 1.64*
Preoccupation with Food	14.88 ± 4.86	14.90 ± 5.06
Feelings of Hunger	14.63 ± 4.19	14.10 ± 2.57
Lack of Control	16.13 ± 7.18	20.90 ± 5.61*
Negative Effect	8.75 ± 3.89	10.30 ± 3.79
Guilty Feelings	5.63 ± 2.42	8.40 ± 3.90*

Values are means ± SD.

***indicates significantly higher scores between groups**

FCQ-S. For the 5 dimensions of food craving that are dependent on physiological and psychological states, 3 x 2 x 2 Mixed Model ANOVAs were used to check for significant main effects. Bonferroni's post-hoc test and one-way ANOVAs were used to compare the lean and overweight groups in the exercise and control trials.

Intense desire to eat. For this dimension, the three significant main effects are: time, time x body type interaction, time x body type x trial. The whole group scores at baseline (Pre) are significantly lower for the lean compared to the overweight group (5.13

± 2.42 vs 8.55 ± 3.40) (One-way-ANOVA, Table 4-3).

Figure 4-3 shows that the mean scores of the lean group in the control trial increase significantly from Pre to 1Hr (4.75 ± 1.04 vs 8.75 ± 2.32) and from Post to 1Hr (5.63 ± 2.88 vs 8.75 ± 2.32). In the exercise trial, the mean score of the lean group increases significantly only from Pre to 1Hr (5.50 ± 3.34 vs 9.63 ± 4.17).

Tables 4-3 and 4-5 and Figure 4-4 show that the mean scores of the overweight group in the control trial are not significantly different; however, the mean score in the exercise trail decreases significantly from Pre to Post (9.00 ± 3.68 vs 5.20 ± 2.49).

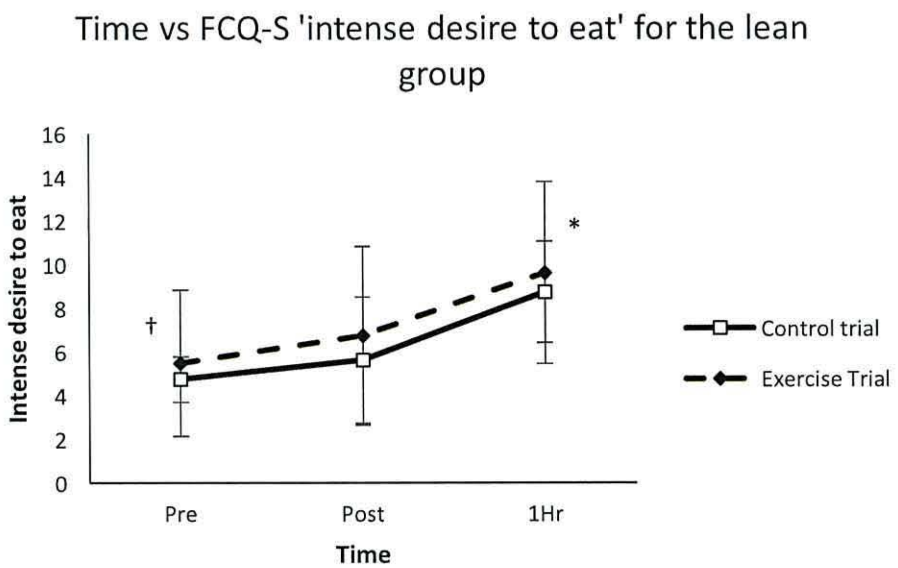

Figure 4-3. Time vs. FCQ-S 'intense desire to eat' for the lean group. All values are means ± SD. * indicates a significant difference from previous time point. † indicates a significant difference between groups.

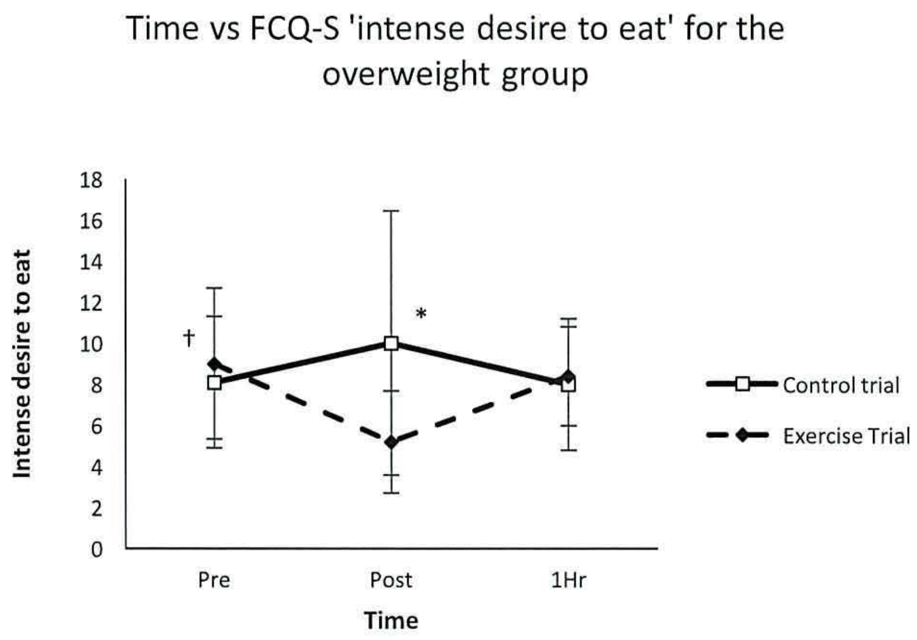

Figure 4.4. Time vs. FCQ-S 'intense desire to eat' for the overweight group. All values are means ± SD. * indicates a significant difference from previous time point. † indicates a significant difference between groups.

Positive Reinforcement. For this dimension, the two significant main effects are: time, time x body type interaction.

Tables 4-3 and 4-4 show that the mean scores for the lean group in both the control and exercise trials show are not significantly different; however the mean score in the control trial increases insignificantly from 5.75 ± 2.12 (Post) to 8.50 ± 3.38 (1Hr) and the mean scores in the exercise trial increase insignificantly from 6.25 ± 3.62 (Pre) through 7.50 ± 4.34 (Post) to 9.50 ± 4.96 (1Hr).

Figure 4-5 shows that the mean scores of the overweight group in the control trial are not significantly different; however, the mean score in the exercise trial increases significantly from Post to 1Hr (5.30 ± 2.26 vs 8.10 ± 2.23).

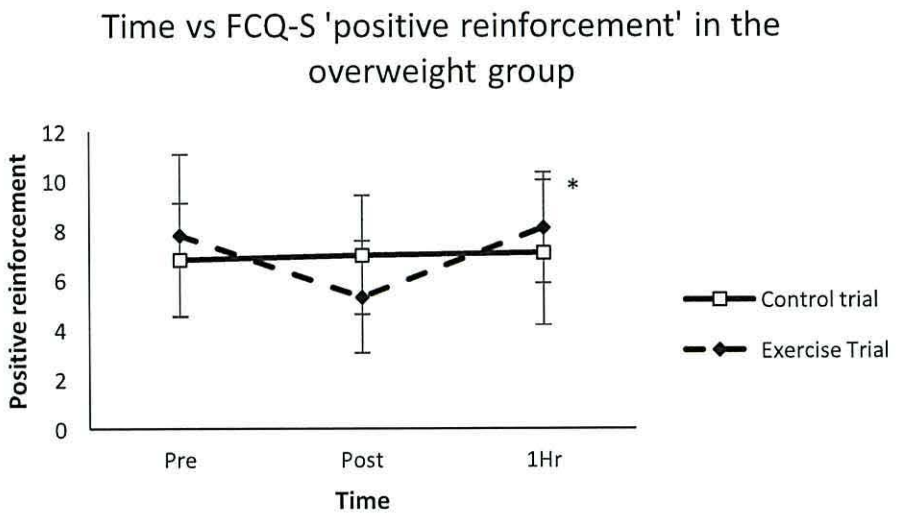

Figure 4.5. Time vs. FCQ-S 'positive reinforcement' in the overweight group. All values are means ± SD. * indicates a significant difference from previous time point.

Negative Reinforcement. For this dimension, there are no significant effects, however the mean score for the lean group in the exercise trial increases insignificantly from 6.88 ± 3.48 (Post) to 9.13 ± 4.26 (1Hr).

Lack of control. For this dimension, the two significant main effects are: time, time x body type interaction. The whole group scores at baseline (Pre) are significantly lower for the lean compared to the overweight group (4.88 ± 2.50 vs 6.35 ± 1.84) (One-way-ANOVA, Table 4-5).

Figure 4.6 shows that the mean scores of the lean group in the exercise trial trend towards increasing significantly from Pre to 1Hr (5.13 ± 3.00 vs 8.13 ± 4.16, p=0.064) and from Post to 1Hr (6.00 ± 3.59 vs 8.13 ± 4.16, p=0.093).

Tables 4-3 and 4-4 show that the mean scores of the overweight group in both the control and exercise trials are not significantly different.

Feelings of hunger. For this dimension, the significant main effect is time.

Figure 4.6 shows that the mean scores of the lean group in the control trial show no significant differences to each other; however the mean scores in the control trial increase insignificantly from 5.63 ± 2.20 (Pre) through 6.25 ± 2.71 (Post) to 8.25 ± 3.50 (1Hr). The mean scores in the exercise trial increase significantly from Pre to 1Hr (5.75 ± 3.11 vs 10.25 ± 3.69) and from Post to 1Hr (7.00 ± 3.82 vs 10.25 ± 3.69).

Tables 4-3 and 4-4 and Figure 4-7 show that the mean scores of the overweight group in the control trial are not significantly different; however the mean scores in the control trial increase insignificantly from 6.50 ± 2.72 (Pre) through 7.70 ± 2.45 (Post) to 8.40 ± 2.27 (1Hr). The mean scores in the exercise trial trend towards increasing significantly from Pre to 1Hr (6.70 ± 2.67 vs 8.30 ± 2.26, p=0.077) and increase significantly from Post to 1Hr (5.80 ± 2.78 vs 8.30 ± 2.26).

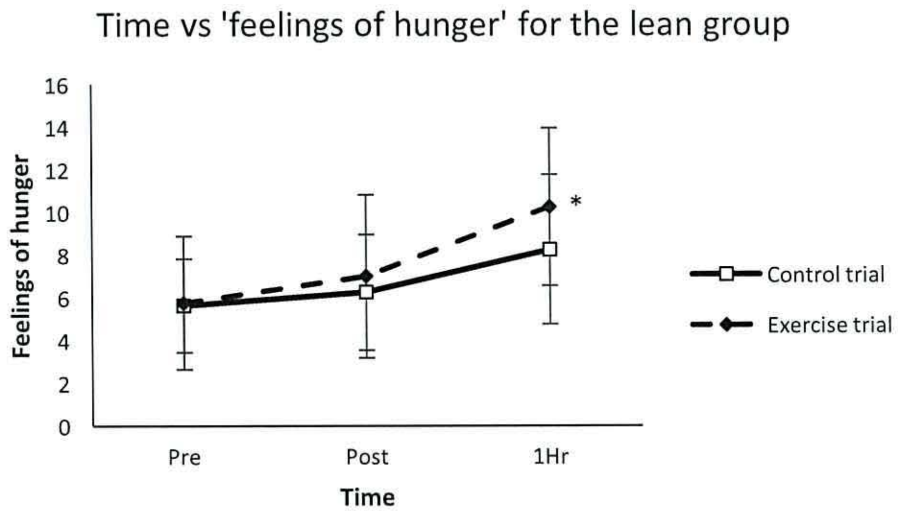

Figure 4.6. Time vs. 'feelings of hunger' for the lean group. All values are means ± SD. * indicates a significant difference from previous time point.

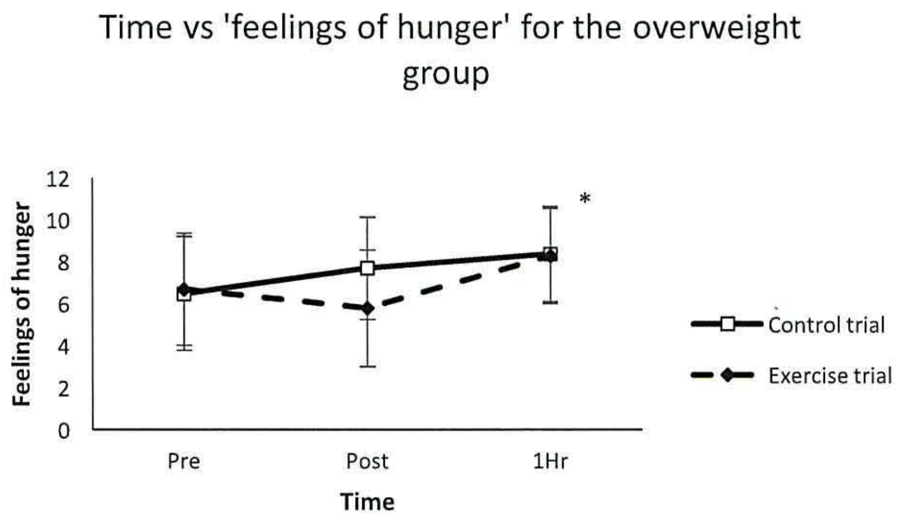

Figure 4.7. Time vs. 'feelings of hunger' for the overweight group. All values are means ± SD. * indicates a significant difference from previous time point.

Table 4-3.

FCQ-S Responses for the Lean and Overweight Groups in the Control Trial.

	Lean Group			Overweight Group		
	Pre	**Post**	**1Hr**	**Pre**	**Post**	**1Hr**
Intense desire to eat	4.75 ± 1.04	5.63 ± 2.88	8.75 ± 2.32*†	8.10 ± 3.21	10.00 ± 6.43	8.00 ± 3.20
Positive reinforcement	5.75 ± 2.32	5.75 ± 2.12	8.50 ± 3.38	6.80 ± 2.30	7.00 ± 2.40	7.10 ± 2.92
Negative reinforcement	6.38 ± 2.93	5.13 ± 2.48	7.38 ± 3.46	6.30 ± 1.34	6.60 ±1.65	6.20 ± 2.39
Lack of control	4.63 ± 2.07	4.88 ± 2.42	7.13 ± 2.70	6.20 ± 1.32	5.30 ± 2.00	6.20 ± 2.94
Feelings of Hunger	5.63 ± 2.20	6.25 ± 2.71	8.25 ± 3.50	6.50 ± 2.72	7.70 ± 2.45	8.40 ± 2.27

Values are means ± SD. n=18 (lean n=8, overweight n=10).

***indicates a significant difference from the previous time point**

†indicates a significant difference between groups at the 'Pre' time point

Table 4-4.

FCQ-S Responses for the Lean and Overweight Groups in the Exercise Trial.

	Lean			Overweight		
	Pre	**Post**	**1Hr**	**Pre**	**Post**	**1Hr**
Intense desire to eat	5.50 ± 3.34	6.75 ± 4.10	9.63 ± 4.17†	9.00 ± 3.68	5.20 ± 2.49*	8.40 ± 2.41
Positive reinforcement	6.25 ± 3.62	7.50 ± 4.34	9.50 ± 4.96	7.80 ± 3.26	5.30 ± 2.26	8.10 ± 2.23*
Negative reinforcement	6.38 ± 2.93	6.88 ± 3.48	9.13 ± 4.26	6.00 ± 2.26	6.20 ± 2.53	6.90 ± 2.85
Lack of control	5.13 ± 3.00	6.00 ± 3.59	8.13 ± 4.16	6.50 ± 2.32	5.30 ± 2.63	6.60 ± 1.43
Feelings of Hunger	5.75 ± 3.11	7.00 ± 3.82	10.25 ± 3.69*†	6.70 ± 2.67	5.80 ± 2.78	8.30 ± 2.26*

Values are means ± SD. n=18 (lean n=8, overweight n=10)

***indicates a significant difference from the previous time point**

†indicates a significant difference between groups at the 'Pre' time point

Table 4-5.

FCQ-S Scores for the Lean and Overweight Groups at Baseline (Pre).

	Lean	Overweight
Intense desire to eat	5.13 ± 2.42	8.55 ± 3.40*
Positive reinforcement	6.00 ± 2.94	7.30 ± 2.79
Negative reinforcement	6.38 ± 2.83	6.15 ± 1.81
Lack of control	4.88 ± 2.50	6.35 ± 1.84*
Feelings of Hunger	5.69 ± 2.60	6.60 ± 2.62

All values are means ± SD. * indicates a significant difference between groups.

Subjective Ratings of Appetite – Phone App

Participants used the phone app to record any 'liking' or 'wanting' events in the time period 24 hours before (Day 1) and after (Day 2) each trial. For the 7 dimensions of 'wanting' and 'liking', 2 x 2 x 2 Mixed Model ANOVAs were used to check for significant main effects. Bonferroni's post-hoc tests and one-way ANOVAs were used to compare the lean and overweight groups in the exercise and control trials.

Frequency of wanting. For this dimension, the significant main effect is the day x body type interaction.

The values for the lean group in the control and exercise trials are not significantly different.

Tables 4-6 and 4-7 show that the values for the overweight group in the control and exercise trials decrease significantly from Day 1 to Day 2.

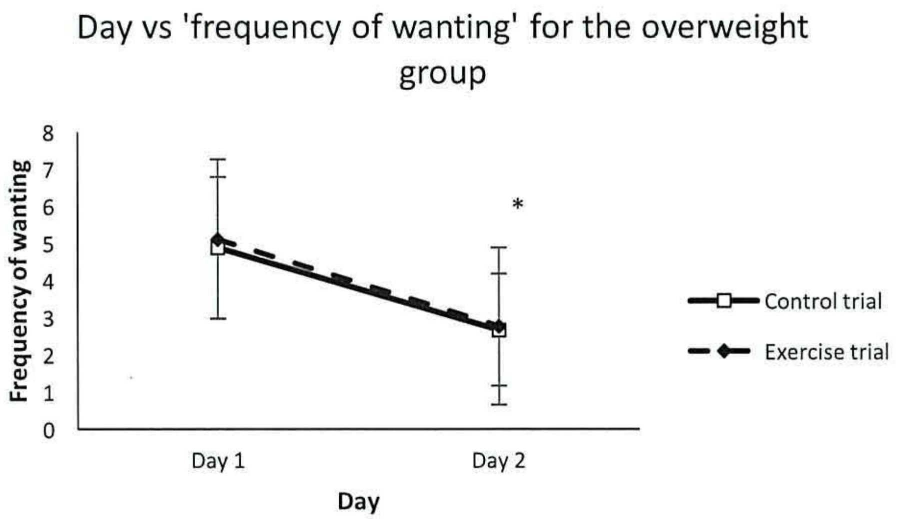

Figure 4.8. Day vs. 'frequency of wanting' for the overweight group.

All values are means ± SD. * indicates a significant difference from previous time point.

Sum of total wanting. For this dimension, the significant main effect is the day x body type interaction.

The values for the lean group in the control and exercise trials are not significantly different.

Tables 4-6 and 4-7 and Figure 9 show that the values for the overweight group in the control and exercise trials decrease significantly from Day 1 to Day 2.

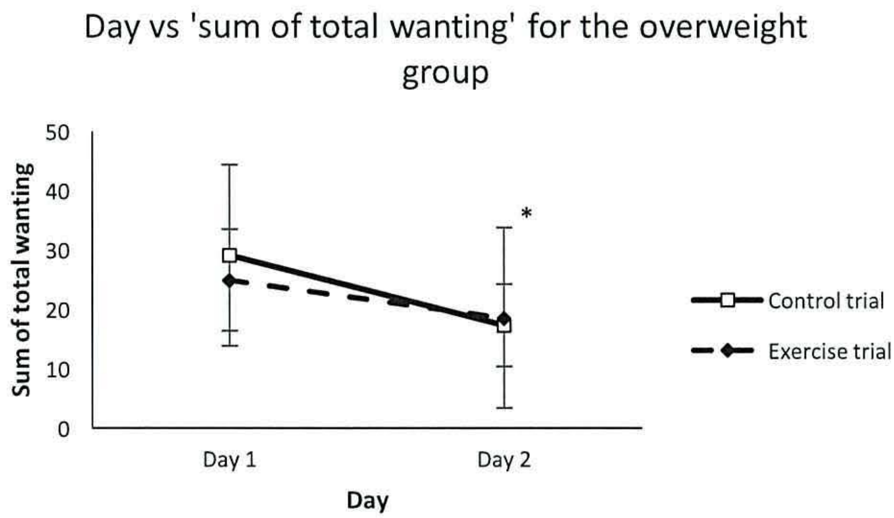

Figure 4.9. Day vs. 'sum of total wanting' for the overweight group.

All values are means ± SD. * indicates a significant difference from previous time point.

Meal frequency. For this dimension, the significant main effects are: day, day x body type interaction. The values for the lean group in the control and exercise trials are not significantly different. Tables 4.6 and 4.7 and Figure 4.10 show that the values for the overweight group in the control trial are not significantly different; however, the value in the exercise trial reduces significantly from Day 1 to Day 2.

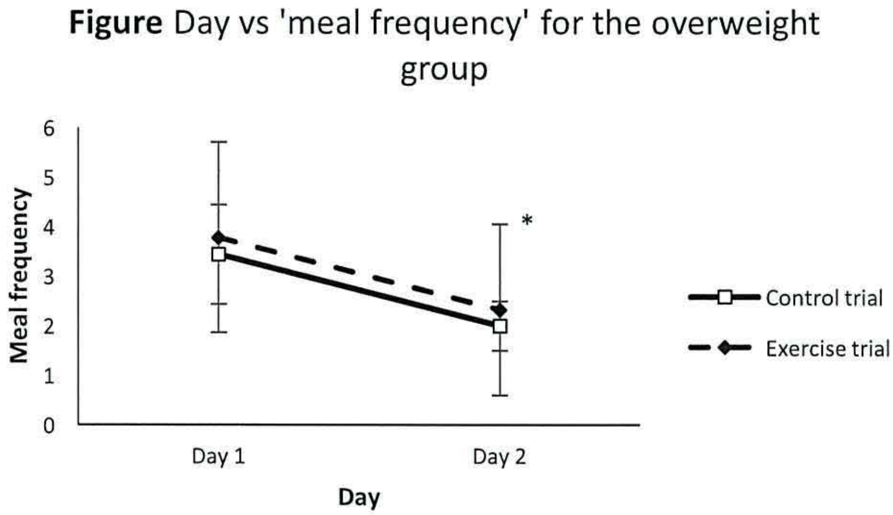

Figure 4.10. Day vs. 'meal frequency' for the overweight group.

All values are means ± SD. * indicates a significant difference from previous time point.

Sum of successful wanting, sum of meal liking, and sum of meal duration. For these dimensions, there are no significant differences between and within the lean and overweight groups .

Resisted wanting. For this dimension, the significant main effect is the day x body type interaction. The value for the lean group in the control trial is trending towards increasing significantly from Day 1 to Day 2 (28.63 ± 47.34 to 157.75 ± 232.63, p=0.086); however, the values in the exercise trial are not significantly different (96.38 ± 97.65 to 186.00 ± 306.46).

Tables 4.6 and 4.7 show that the values for the overweight group in the control trial are not significantly different; however, the value in the exercise trial is trending towards reducing significantly from Day 1 to Day 2 (64.67 ± 67.76 to 22.44 ± 38.47, p=0.057).

Table 4-6.

Phone Application Dimension Responses for the Lean and Overweight Groups in the Control Trial.

	Lean		**Overweight**	
	Day 1	**Day 2**	**Day 1**	**Day 2**
Frequency of wanting	3.75 ± 1.28	4.75 ± 2.61	4.89 ± 1.90	2.67 ± 1.50*
Sum of total wanting	24.88 ± 7.74	35.63 ± 21.84	29.11 ± 15.28	17.33 ± 6.91*
Meal Frequency	3.13 ± 0.99	2.63 ± 1.06	3.44 ± 1.01	2.00 ± 0.50
Sum of successful wanting	21.88 ± 5.84	19.88 ± 9.75	20.44 ± 7.83	13.67 ± 2.24
Sum of Meal liking	20.63 ± 9.20	20.13 ± 11.92	22.78 ± 9.47	15.33 ± 4.06
Sum of meal duration (hrs)	1.02 ± 0.80	0.91 ± 0.77	1.16 ± 0.90	1.15 ± 1.28
Resisted wanting	28.63 ± 47.34	157.75 ± 232.63	91.00 ± 93.20	27.00 ± 47.26

Values are means ± SD. n=17 (lean n=8, overweight n=9)

*indicates a significant difference from the previous time point

Table 4-7.

Phone Application Dimension Responses for the Lean and Overweight Groups in the Exercise Trial.

	Lean		Overweight	
	Day 1	**Day 2**	**Day 1**	**Day 2**
Frequency of wanting	4.50 ± 2.07	5.50 ± 4.00	5.11 ± 2.15	2.77 ± 2.11*
Sum of total wanting	31.13 ± 12.86	34.38 ± 26.77	24.89 ± 8.54	18.56 ± 15.22*
Meal Frequency	2.75 ± 1.04	3.50 ± 1.60	3.78 ± 1.92	2.33 ± 1.73*
Sum of successful wanting	21.38 ± 8.03	22.63 ± 11.93	18.22 ± 4.69	15.78 ± 13.45
Sum of Meal liking	21.63 ± 7.61	23.12 ± 12.56	22.00 ± 10.70	15.33 ± 13.29
Sum of meal duration (hrs)	0.93 ± 0.43	8.86 ± 22.69	0.68 ± 0.37	0.52 ± 0.36
Resisted wanting	96.38 ± 97.65	186.00 ± 306.46	64.67 ± 67.76	22.44 ± 38.47

Values are means ± SD. n=17 (lean n=8, overweight n=9)

*indicates significant difference from previous time point

Correlations between Tools

The data for subjective appetite ratings (FCQ-T and FCQ-S, baseline) and the phone app (Day 1) were assessed for correlations both in the whole group and in the lean and obese groups considered separately.

Whole group. With both the lean and obese groups combined, there is a significant positive correlation between the FCQ-T dimension of 'positive reinforcement' is significantly positively correlated to 4 phone app dimensions: 'frequency of wanting' ($r=0.374$, $p=0.030$), 'meal frequency' ($r=0.395$, $p=0.021$), 'sum of successful wanting' ($r=0.387$, $p=0.024$), and 'sum of meal liking' ($r=0.572$, $p=0.000$). There are no significant correlations between the 9 FCQ-T dimensions and the remaining 3 phone app dimensions or between the 5 FCQ-S dimensions and the 7 phone app dimensions (Table 4.8).

Table 4-8.

Correlations for the Whole Group between the Phone Application and FCQ-T Dimensions.

	Frequency of wanting	Sum of total wanting	Meal Frequency	Sum of successful wanting	Sum of Meal liking	Sum of meal duration	Resisted wanting
Positive Reinforcement	r=0.374 p=0.030		r=0.395 p=0.021	r=0.387 p=0.024	r=0.572 p=0.000		
Negative Reinforcement							
Intentions to Eat							
Cue Dependent Eating							
Preoccupation with Food							
Feelings of Hunger							
Lack of Control							
Negative Effect							
Guilty Feelings							

Lean group. Within the lean group there is a significant positive correlation between the phone app dimension of 'sum of successful wanting' and 4 FCQ-T dimensions: 'negative reinforcement' (r=0.498, p=0.050), 'feelings of hunger' (r=0.498, p=0.050), 'preoccupation with food' (r=0.544, p=0.029), and 'negative effect' (r=0.505, p=0.046). There are no significant correlations between the remaining 5 FCQ-T dimensions and the remaining 6 phone app dimensions or between the 5 FCQ-S dimensions and the 7 phone app dimensions (Table 4.9).

Table 4-9.

Correlations for the Lean Group between the Phone Application and FCQ-T Dimensions.

	Frequency of wanting	**Sum of total wanting**	**Meal Frequency**	**Sum of successful wanting**	**Sum of Meal liking**	**Sum of meal duration**	**Resisted wanting**
Positive Reinforcement							
Negative Reinforcement				r=0.498 n=0.050			
Intentions to Eat							
Cue Dependent Eating							
Preoccupation with Food				r=0.544 p=0.029			
Feelings of Hunger				r=0.498 p=0.050			
Lack of Control							
Negative Effect				r=0.505 p=0.046			
Guilty Feelings							

Overweight group. Within the overweight group there is a significant positive correlation between the FCQ-T dimension of 'positive reinforcement' and 3 phone app dimensions: 'frequency of wanting' (r=0.536, p=0.022), 'meal frequency' (r=0.521, p=0.027), and 'sum of meal liking' (r=0.574, p=0.013). There is also a significant positive correlation between the FCQ-S dimension of 'positive reinforcement' and 2 phone app dimensions: 'frequency of wanting' (r=0.609, p=0.007) and 'resisted wanting' (r=0.494, p=0.037). There are no significant correlations between the remaining 8 FCQ-T dimensions and the remaining 4 phone app dimensions or between the remaining 4 FCQ-S dimensions and the remaining 5 phone app dimensions (Tables 4-10 and 4-11).

Table 4-10.

Correlations for the Overweight Group between the Phone Application and FCQ-T Dimensions.

	Frequency of wanting	**Sum of total wanting**	**Meal Frequency**	**Sum of successful wanting**	**Sum of Meal liking**	**Sum of meal duration**	**Resisted wanting**
Positive Reinforcement	r=0.536 p=0.022		r=0.521 p=0.027		r=0.574 p=0.013		
Negative Reinforcement							
Intentions to Eat							
Cue Dependent Eating							
Preoccupation with Food							
Feelings of Hunger							
Lack of Control							
Negative Effect							
Guilty Feelings							

Table 4-11.

Correlations for the Obese Group between the Phone Application and FCQ-S (Pre) Dimensions.

	Frequency of wanting	**Sum of total wanting**	**Meal Frequency**	**Sum of successful wanting**	**Sum of Meal liking**	**Sum of meal duration**	**Resisted wanting**
Intense desire to eat							
Positive reinforcement	r=0.609 p=0.007						r=0.494 p=0.037
Negative Reinforcement							
Lack of control							
Feelings of Hunger							

Scatter Plots

Figures 4.11 and 4.12 shows scatter plots for the 'wanting' scores of all participants in the exercise trial. Time is normalised for all participants to values -24 hours and +24 hours from the time of the trial in the laboratory (i.e. 0 hours). For the overweight group, wanting scores shift from a lower to a higher level before and after the exercise trial, respectively. However, for the overweight group in the control trial and for the lean group in both trials, no differences are observed in the levels before or after the trials .

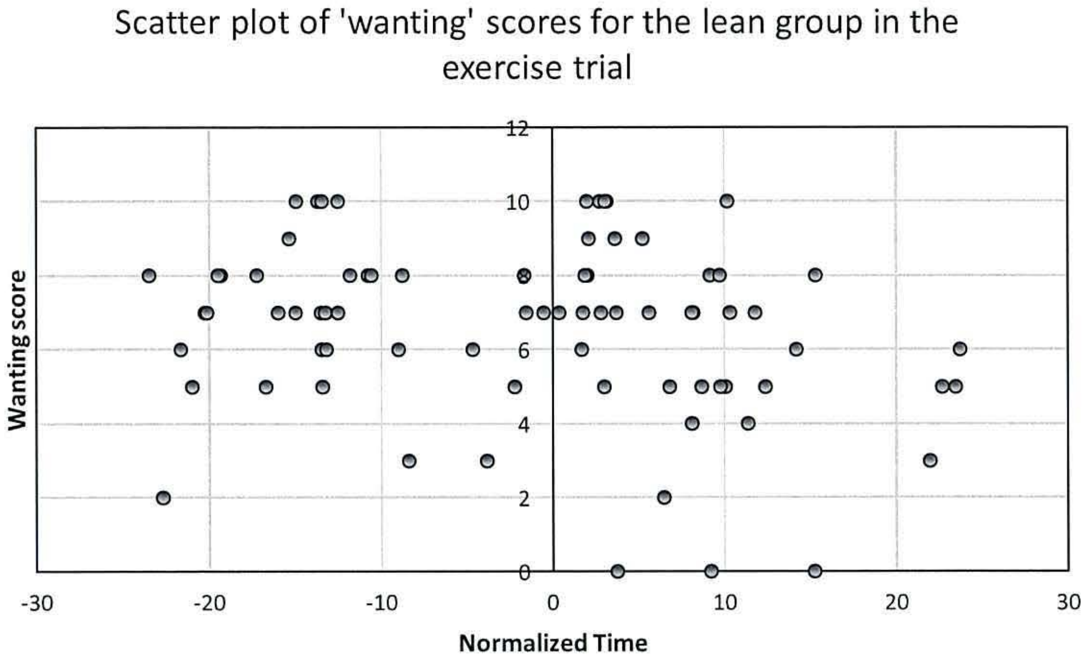

Figure 4.11. Scatter plot of 'wanting' scores for the lean group in the exercise trial.

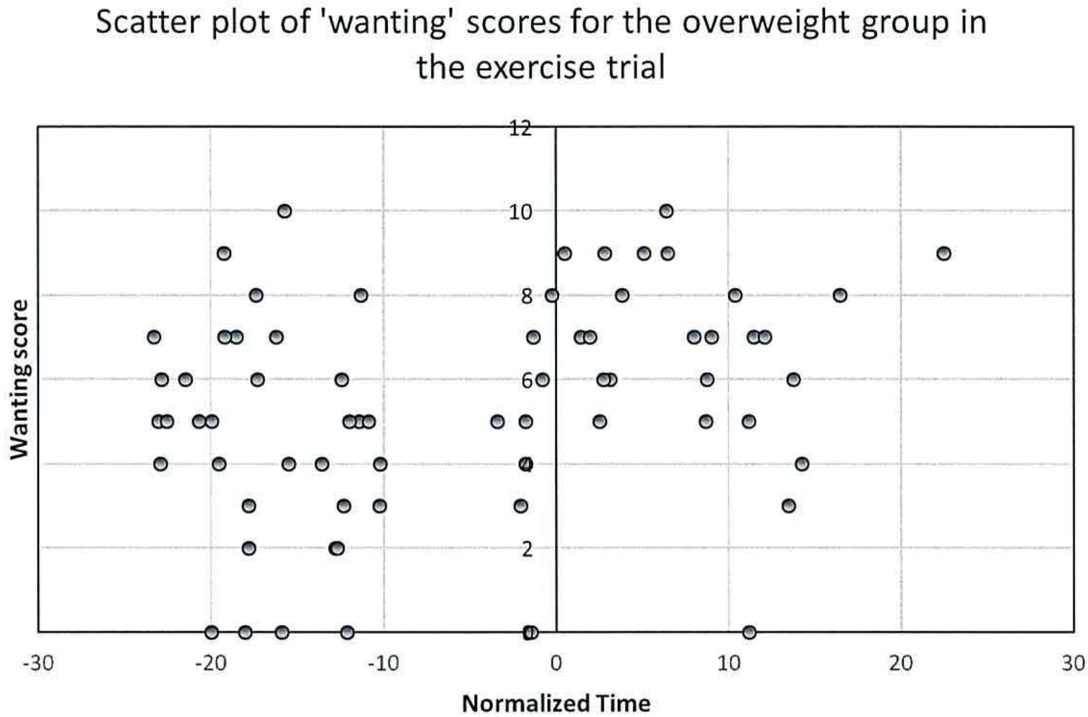

Figure 4.12. Scatter plot of 'wanting' scores for the overweight group in the exercise trial.

4.4 Discussion

This research has studied the physiological and psychological dimensions of eating behaviour before (Pre), after (Post), and 1 hour after (1Hr) exercise in sedentary lean and overweight individuals. In particular, four hypotheses were generated from the research question, 'How does an individual's BMI affect the 'liking' and 'wanting' responses in the 24 hours after exercise?' These hypotheses were tested by comparing data for all 19 sedentary participants (8 lean and 10 overweight) in the control (i.e. watching a non-dramatic movie) and exercise trials. The four types of measurements collected by the tools were:

- Anthropometric data on height, body mass, body composition and $VO_{2\,max}$
- Ratings of subjective appetite from two questionnaires:
  - FCQ-T for 9 food craving dimensions (independent of physiological or psychological state).
  - FCQ-S for 5 food craving dimensions (dependent on physiological or psychological state).
- Continuous data on 'liking' and 'wanting' events from the 'Minding Eating' phone application for 7 food craving dimensions for 24 hours both before and after the trials.

The following sections will summarise the significant results for each of these measurement types and for any correlations between them. These four hypotheses will then be tested against these findings in the context of the existing literature. Finally, the rationale for this study will be revisited and the strengths and limitations of the study will be assessed along with recommendations for future research.

Anthropometric Measurements

Compared to the lean group, the overweight group had significantly higher averages for BMI, percentage body fat, and weight. However, the two groups did not differ significantly for average age or cardiorespiratory fitness (VO_{2max}).

Caspersen et al. (1985) showed a correlation between VO_{2max} and physical activity. Therefore, since all lean and overweight participants in this study were sedentary, i.e. they did not exercise regularly, differences in their BMI and body fat content were assumed to be created by differences in physiological and psychological factors.

Ratings of Subjective Appetite: FCQ-T

For the responses taken 1 week before the trial, only 3 dimensions differed between the two groups; 'guilty feelings' (guilt felt for food cravings and/or the lack of control over them), 'lack of control' (the loss of control over eating before and during eating), and 'cue dependent eating' (the triggering of food cravings by environmental cues) were significantly higher for the overweight compared to the lean group. The remaining 6 dimensions showed no significant differences between the groups: 'positive reinforcement', 'negative reinforcement', 'feelings of hunger', 'intentions to eat', 'negative effect', and 'preoccupation with food'.

Ratings of Subjective Appetite: FCQ-S

For the baseline responses taken before (Pre) the control and exercise trials, two dimensions differed between the two groups; the 'intense desire to eat' (the intensity of the desire to eat a specific food) and 'lack of control' (the loss of control over eating before and during eating) were significantly higher for the overweight group compared to the lean group. The remaining 3 dimensions did not differ significantly between the groups: 'positive reinforcement', 'negative reinforcement', and 'feelings of hunger'.

For the responses taken immediately after the trials (Post), only one dimension differed significantly from the previous time point (Pre). 'The intense desire to eat' was significantly lower for the overweight group in the exercise trial, whereas there were no significant differences for the lean group in the exercise trial or for the two groups in the control trial.

For the responses taken 1 hour after the trials (1Hr), none of the dimensions differed significantly from the previous time points (Post) for the lean or overweight groups except for four differences. Firstly, for the lean group in the control trial (i.e. not in the exercise trial), the 'intense desire to eat' increased significantly. Secondly, for both the lean and overweight groups in the exercise trial, 'feelings of hunger' increased significantly. Thirdly, for the overweight group in the exercise trial, 'positive reinforcement' increased significantly. Fourthly, for the lean group in the exercise trial, 'lack of control' trended towards increasing significantly.

In general, from Pre to 1Hr, scores did not change or they increased insignificantly for all dimensions. However, 'intense desire to eat' did increase significantly for the lean group in both trials, and 'lack of control' trended towards increasing significantly (p=0.064) for the lean group in the exercise trial. Furthermore, 'feelings of hunger' increased significantly for the lean group in the exercise trial, and trended towards increasing significantly (p=0.077) for the overweight group in the exercise trial.

Ratings of Subjective Appetite: Phone App

For the data on 'liking' and 'wanting' events taken 24 hours either side of the trial, only 4 phone app dimensions differed significantly for the two groups between Day 1 and Day 2. Firstly, 'frequency of wanting' (the number of 'wanting' events per unit time), and 'sum of total wanting' (the sum of the 'wanting' scores for all 'wanting' events in a unit of time) were significantly lower for the overweight compared to the lean group in the control and exercise trials. Secondly, 'meal frequency' (the number of 'wanting' events per unit time that led to meal intake) was significantly lower for the overweight compared to the control trial or to the lean group in the exercise and control trials. Thirdly, 'resisted wanting' (a 'wanting' event where meal intake is resisted) trended towards increasing significantly (p=0.086) for the lean group in the control trial. Conversely, 'resisted wanting' trended towards decreasing significantly (p=0.057) for the overweight group in the exercise trial. In addition, the remaining 3 dimensions did not differ significantly between the groups or trials: 'sum of successful wanting', 'sum of meal liking', and 'sum of meal duration'.

Finally, for the overweight group (but not for the lean group or in the control trials), total wanting scores increased to a higher level following exercise.

Correlations between the FCQ and Phone App Dimensions

Whereas the previous sections described the relationships between the 'liking' and 'wanting' events for lean and overweight groups in relation to the times before and after exercise, this section will describe the correlations between the 'liking' and 'wanting' events for lean and overweight groups in general.

For the overweight group, the FCQ-T dimension of 'positive reinforcement' (the anticipated positive emotional reward from eating) was significantly positively correlated to 3 phone app dimensions: 'frequency of wanting' (the number of 'wanting' events per unit time), 'meal frequency' (the number of 'wanting' events per unit time that led to meal intake) and 'sum of meal liking' (the sum of 'liking' scores for all 'liking' events after meal intake). The FCQ-S dimension of 'positive reinforcement' was also significantly positively correlated to 2 phone app dimensions: 'frequency of wanting' (the number of 'wanting' events per unit time) and 'resisted wanting' (a 'wanting' event where meal intake is resisted).

For the lean group, the phone app dimension of 'sum of successful wanting' (the sum of wanting scores in a unit of time that led to meal intake) was significantly positively correlated to 4 FCQ-T dimensions, most of which are physiological indicators: 'negative reinforcement' (the anticipated relief from negative emotions after eating), 'feelings of hunger' (general feelings of hunger or fullness), 'preoccupation with food' (thoughts or a preoccupation with food), and 'negative effect' (the effect of negative emotions on food craving or eating).

Research Hypotheses

This section will take the results from the previous section for FCQ-S and the phone app and use them to test each of the four hypotheses.

1) Exercise will affect the time pattern, scores, and frequency of 'liking' and 'wanting' events in both lean and overweight individuals.

There is strong evidence for this hypothesis. Exercise created significant differences in the 'liking' and 'wanting' events for the lean and overweight groups and in the control and exercise trials.

2) Post-exercise physiological hunger will be suppressed temporarily in both lean and overweight individuals.

There is no evidence for this hypothesis. The two FCQ-S dimensions that measure physiological hunger (i.e. 'negative reinforcement' and 'feelings of hunger') were not suppressed immediately following exercise (Post). In fact, feelings of hunger for both the lean and overweight groups increased significantly (Post to 1 Hr) following the exercise trial. These increases in 'feelings of hunger' were consistent with an overall increase in this dimension from Pre to 1Hr in the exercise trials; i.e. it increased significantly for the lean group and trended towards increasing significantly for the overweight group. Finally, the second indicator of physiological hunger, 'negative reinforcement', showed no significant differences between either the lean and obese groups or the exercise and control trials.

The three physiological FCQ-T dimensions, i.e. 'negative reinforcement', 'feelings of hunger', and 'negative effect' were significantly positively correlated (along with the hedonic dimension 'preoccupation with food') with the phone app dimension 'sum of successful wanting' (the sum of wanting scores in a unit of time that led to meal intake). This implies that, in lean individuals, successful meal intake was influenced mainly by physiological factors, as well as by hedonic ones. However, 'sum of total wanting' (i.e. total 'wanting') was not correlated to any of these physiological factors or to 'sum of successful wanting'. Therefore, although both hedonistic and physiological events were experienced by lean sedentary individuals, it was the underlying physiological drivers that influenced the action of eating itself and, therefore, that regulated BMI and body fat at healthy levels.

3) The 'liking' scores of lean individuals will be higher after exercise than at baseline, whereas no differences will occur for overweight individuals.

There is no evidence for this hypothesis. No significant differences were found from Day 1 to Day 2 for the 'sum of meal liking' and 'meal duration dimensions' between either the lean or overweight groups or in the exercise or control trials.

4) The 'wanting' scores in the 24 hours following exercise will increase or decrease above baseline for overweight or lean individuals, respectively.

There is strong evidence against this hypothesis, since the opposite relationship was statistically significant. For the overweight group in the exercise trial, the FCQ-S dimension 'intense desire to eat' decreased significantly from Pre to Post and the phone app dimensions 'meal frequency' and 'resisted wanting' decreased significantly or trended towards decreasing significantly, respectively, from Day 1 to Day 2.

For the lean group in the control trial, 'intense desire to eat' (Post to 1 Hr and Pre to 1Hr) increased significantly and 'resisted wanting' trended towards increasing significantly from Day 1 to Day 2. Given this context, there were no significant differences from the control results following exercise. In fact, 'lack of control' trended towards increasing significantly from Pre to 1Hr and from Post to 1Hr in the exercise trial.

Surprisingly, the FCQ-S dimension of 'positive reinforcement' increased significantly from Post to 1Hr for the overweight group in the exercise trial only. However, in the FCQ-T responses for this group, the same dimension was correlated positively and significantly with the phone app dimensions 'frequency of wanting', 'meal frequency' and 'sum of meal liking'. Furthermore, in the FCQ-S responses for this group, this dimension was correlated positively and significantly to the phone app dimensions 'frequency of wanting' and 'resisted wanting'. This is a contradiction in the overweight group results; 'frequency of wanting' reduced significantly from Day 1 to Day 2 in both the exercise and control trials, 'meal frequency' reduced significantly from Day 1 to Day 2 in the exercise trial, 'sum of meal liking' showed no significant differences between trials, and 'resisted wanting' trended towards reducing significantly from Day 1 to Day 2 in the exercise trial.

Comparison to previous findings

King et al. (1994 and 1996) and Martins et al. (2007) also found that some craving dimensions were suppressed temporarily following exercise for the overweight, but not for the lean, group. This temporary post-exercise suppression (of the 'intense desire to eat') for the overweight group may have caused the significant reduction in meal intake from Day 1 to Day 2 as indicated by the 'meal frequency' dimension (King et al., 1994). In addition, the reversion of craving scores back to baseline or higher within one hour of exercise is also consistent with previous studies (Broom et al., 2009; King et al., 2010). It is possible that suppression of craving can be detected only when craving scores exceed a certain threshold. Therefore, the significantly lower baseline scores for two of five FCQ-S craving dimensions ('intense desire to eat', and 'lack of control') could have concealed the effects of any suppression in the lean group.

Compensatory eating behaviour could also be subject to threshold effects. For example, compensatory eating behaviour in overweight men has been noted following 950 kcals of exercise, but not for 300 kcals (Rosenkilde et al., 2012). Therefore, the reason that the phone app dimensions 'frequency of wanting' and 'sum of total wanting' reduced significantly for the overweight group in both trials from Day 1 to Day 2 could be because the 300-kcal exercise trial was not intensive enough. However, this does not explain why the phone app dimension 'resisted wanting' trended towards reducing significantly for the overweight group following exercise. Therefore, an alternative explanation is that the overweight group may have eaten more food during each meal. However, there are no indications of this; 'meal frequency' reduced significantly for the overweight group in the exercise trial from Day 1 to Day 2, and there was no significant correlation between 'frequency of wanting' and 'sum of total wanting' to 'sum of meal duration'.

The FCQ-T and FCQ-S wanting dimensions for the overweight group were highly correlated to the hedonic factor 'positive reinforcement' and showed no correlation to the physiological dimensions that appeared to drive successful wanting for the lean group, i.e. to 'negative reinforcement', 'feelings of huger', and 'negative effect'. This supports the hypothesis that 'wanting' in the overweight group may act independently of or even override homeostatic mechanisms that regulate energy intake (Finlayson et al., 2008a; Mela, 2006). Therefore, the positive emotions that have been associated by experience to eating particular foods (Berridge et al., 2010; Saper et al., 2002) are expected to influence whether 'liking' and 'wanting' events lead to meal intake. However, this study showed no correlations between 'positive reinforcement' and increased 'sum of successful wanting', 'sum of meal duration', or 'meal frequency'.

Finally, the scores for the FCQ-T dimensions 'cue dependent eating', 'lack of control', and 'guilty feelings' were all higher for the overweight group. This shows that overweight individuals were more susceptible to environmental and social cues than were lean individuals (Egger and Swinburn, 1997; Lake and Townshend, 2006; Chaput et al., 2011). In particular, this study has highlighted the significance of 'positive reinforcement' on the eating behaviour of overweight individuals, and the role of the modern obesogenic environment in the learning of positive reward responses that result in an imbalance between energy expenditure and intake (Fields et al., 2007).

4.5 Limitations

Firstly, the exercise amount undertaken (300 Kcals), might be not proper amount to bring about compensatory of eating. Participants for this study all had RPEs over 15 during the last ten minutes of their exercise bout and it is likely that a larger amount of exercise could not be completed. This could be a general limitation of using sedentary populations in an exercise study.

Second, the "Mind Eating" Application can be only used by Androids and I-phone users. This will limited the population and users of other smart and non-smart phone will not be able to be part of the population.
Third, drink data hadn't been analysed in this study as which might be there is effect for the drink on the individuals perception and reward. This limitation should consider further research in future.

Another limitation is the relatively small size of the study. Also the study had a mixed gender population so it does not account for gender differences in eating behaviour.

Future research required a larger sample sizeTo improve the statistical power of study. Research in the future could also look into gender differences in eating behaviour, having male and female populations studied separately and compared versus each other. Further development of phone application could help differentiating between caloric and non-caloric drinks and therefore record valuable data on wanting and liking of drink as well.

4.6 Conclusion

Exercise caused a significant reduction in intense desire to eat immediately after and reduction in perception of wanting and meal frequency with no reduction in meal duration, 24 hours after exercise. Moreover, lean group, 'wanting' and 'liking' were associated with both physiological and hedonic dimensions of eating behaviour, while the overweight group had significant associations with only hedonic dimensions (positive reinforcement). With these findings it becomes evident that overweight/obese individuals seem perceive more related to hedonic drives compared to lean individuals and this might lead to overcompensation by missing out on homeostatic regulation.

CHAPTER 5

5. GENERAL DISCUSSION

5.1 A Summary of the Studies Findings and Discussion .

The regulation of appetite in overweight and obese subjects remains a poorly understood subject and it is unclear whether it is dominated by homeostatic/physiological responses or by hedonic/psychological responses of 'liking' and 'wanting' (Blundell & Finlayson, 2004). Up until recently, questionnaires and highly controlled laboratory based investigations using computer based tests were the only investigations of 'wanting' and 'liking' towards food. Our research aimed to investigate the continuous patterns of 'liking' and 'wanting' components of eating in real-life scenarios by employing a new approach to assess the components of the hedonic response. The goal was to address a huge knowledge gap in the understanding of people's eating behaviours and contribute to the future development of more efficient interventions for overeating and obesity.

In Study 1, we developed and piloted a smart phone application (Mind Eating) that assessed the hedonic components 'wanting' and 'liking' in real-time. The 'wanting' component captured the hedonic (craving, reward expectations) and homeostatic (hunger, appetite) aspects, and 'liking' included palatability and satisfaction (consummatory reward). We tested the use and acceptance of the application on a group of 22 participants and investigated the capability and reality of the application before it could be used for research purposes. The application was improved four times over a period of 12 months. To ensure that the quality of the collected data was consistent, it was decided that the optimal length of application use should be set to two weeks. The performance of the Mind Eating application was analyzed in-depth and it was observed that the scores corresponded with the behavioral patterns of the users. Since this application does not depend on recall and prediction, it enabled us direct targeting of explicit hedonic components and of the homeostatic aspects of eating. Also, the frequency of eating and meal duration were recorded, which could help explore eating behaviour more in-depth. It was felt that the accuracy of the application as well as its technological aspects were meeting our research requirements therefore we could proceed to the next phase of the research where the application was used for data collection in free-living subjects.

In study 2, the Mind Eating application was utilised to gain a deeper insight into the psychological drivers of overweight and obesity. A group of high body fat percentage (H-fat) individuals was compared with a group of low body fat (L-fat) percentage controls. The total sample consisted of 53 adults (H-Fat; n = 20 and L-Fat; n = 33). Participants were asked to score their 'wanting' and 'liking' over a period of two weeks, which enabled us to analyse continuous patterns of 'wanting' and 'liking' of food in real life situations. The following categories of scores were of interest to the analysis: 'wanting' leading to eating events (WE), 'wanting' that did not lead to eating ('wanting' but resisting events, WR) and 'liking' after eating events (L). It was hypothesised that obese people would exhibit different food 'wanting', 'liking' and eating patterns compared with lean controls. We also measured participants' cravings using The Food Craving Questionnaire (FCQ) and their implicit and explicit attitudes toward healthy and unhealthy food. Data was analysed in two stages: the first stage was an aggregate data analysis and the second was a time series analysis.

In Study 3, we added the exercise component to our study of eating behaviour. We studied the physiological and psychological dimensions of eating behaviour before (Pre), after (Post), and 1 hour after (1Hr) exercise in sedentary lean and overweight individuals. We investigated how 'liking' and 'wanting' events, as recorded by the smartphone application, were influenced by a single bout of exercise. Eight sedentary lean and ten sedentary overweight individuals were included in our pilot study. In this study, participants were divided into different groups according to their BMI and not according to fat percentage as in Study 2. We examined how an individual's BMI affected the 'liking' and 'wanting' responses in the 24 hours after exercise session. The participants also completed the Food Cravings Questionnaire (FCQ-T and FCQ-S) that enabled us to differentiate between the physiological and psychological dimensions of eating behaviour and cravings. Ratings of subjective appetite from FCQ-T and FCQ-S, continuous data of 'wanting' and 'liking' from the Mind Eating application and anthropometric measurements (weight, body mass, body composition) were correlated to test our four hypothesis:

1) Exercise will affect the time pattern, scores, and frequency of 'liking' and 'wanting' events in both lean and overweight individuals.

2) Post-exercise physiological hunger will be suppressed temporarily in both lean and overweight individuals.

3) The 'liking' scores of lean individuals will be higher after exercise than at baseline, whereas no differences will occur for overweight individuals.

4) The 'wanting' scores in the 24 hours following exercise will increase or decrease above baseline for overweight or lean individuals, respectively.

A discussion of findings from studies 2 and 3 is presented below.

1.1.1 Frequency of Food Wanting and Eating Events

In Study 2, the aggregate data analysis of the number of food events indicated that the group of L-fat participants recorded significantly more food 'wanting' and food eating events than did the group of H-fat participants. On average, L-Fat participants recorded 1.25 times as many 'wanting' events and 1.21 times as many eating events than the H-Fat group. Several studies already explored the association between eating frequency and obesity, but the results were inconclusive and the role of eating frequency in obesity development has been widely debated. It has generally been accepted that frequency is just one of the factors that influences weight gain (Chaput et al., 2014). Our study supports this notion and is also in agreement with the findings of Ma et al. (2002) that a greater number of eating events might present a lower risk of obesity. Small, frequent meals have previously been suggested as a method of controlling appetite. However, a recent study by Perrigue, Drewnowski, Wang and Neuhouser (2016) found that higher eating frequency did not decrease appetite in healthy adults and could not be considered a strategy for weight loss in isolation from other factors. For instance, energy intake per meal might play a more significant role (Mills et al., 2011). Also, a literature review by Palmer, Capra and Baines (2009) showed that there was no association between eating frequency and weight and health.

When exploring the role of other factors in weight gain and weight maintenance, an American study suggested that there was an association between meal frequency and the quality of diet. Healthy individuals with higher meal frequency and snack frequency were found to generally eat healthier food (Murakami & Livingstone, 2015). The findings of our study could also be used to speculate about the characteristics of food choices of H-fat and L-fat individuals by looking at other characteristic of their eating behaviour. The reported meal duration was approximately 17 minutes in both H-fat and L-fat group, which is in accordance with earlier reports of meal durations of 16 to 22 minutes depending on meal size (Spiegel, 1993). Slower eating has previously been linked to lower body weight (Zhu & Hollis, 2014), but our study did not show a significant difference in meal duration between the two groups. This finding could imply that to maintain higher body mass, H-fat individuals probably needed to choose food with higher caloric density which has already been suggested by Mesas (2011). McKenna et al. (2016) noted that obese individuals are generally assumed to evaluate high caloric, palatable foods more positively than their lean peers, which increases their consumption of unhealthy food. However, this has not always been reflected in research findings (McKenna et al., 2016).

1.1.2 Food Cravings in High-Fat Participants

The food craving questionnaire (FCQ-T) scores collected during study 2 were significantly higher for those in the H-Fat group compared to those in the L-Fat group. This was an interesting finding since H-fat participants had less 'wanting' and eating events than L-fat group. It appears that there was a discrepancy between H-fat participants' eating behaviours recorded in real time using the mobile phone application and their accounts of their everyday cravings. Since The Food Cravings Questionnaire is a valid and reliable instrument and is commonly used to assess cravings (Meule, Hermann, &Kübler, 2014), the finding might suggest that there were other factors that influenced the use of the application and that contributed to the unexplained inconsistency in our findings.

The H-fat group also revealed strong positive correlations between craving trait domains and *resisted wanting*, which was also positively correlated with BMI and body fat in this group, while the L-group reported no significant correlations in the former and latter. We interpret this towards a stronger influence of hedonic mechanisms in the H-group for the choices to eat or to resist rather than cognitive mechanisms and physiological drives. Study 3 provided further evidence about the importance of hedonic mechanisms in overweight and obese individuals. For overweight individuals, 'frequency of wanting', 'meal frequency' and 'resisted wanting' were all correlated to the anticipated positive emotional reward from eating. Furthermore, the FCQ-T and FCQ-S for the overweight group were highly correlated to the hedonic factor of positive reinforcement, but showed no correlation to the physiological dimensions that was present in the lean group. While the lean individual's drive to eat was motivated by both hunger and hedonic components, this was not so clear for the overweight group. Study 3 therefore suggested that in overweight individuals appetite is regulated by hedonic/psychological responses of 'liking' and 'wanting'. Stronger hedonic drive in obese people has previously been suggested (Mela, 2006), however, some authors argue that there are two types of obesity – metabolic obesity and hedonic obesity (Yu et al., 2015). In support of our findings of higher craving scores and stronger hedonic drive in obese people, it has previously been suggested that elevated reward sensitivity in combination with reduced impulse control could be crucial for overeating, particularly in an environment that is obesogenic (Guerrieri, 2007).

1.1.3 Reward from eating

Increased reward sensitization (Davis, 2005), increased reward anticipation (Pelchat, 2004), consummatory reward deficiency (Blum, 2012), and an impaired prediction and learning of food reward values (Berridge 2012; Zhang, 2014) have all been proposed as important mechanisms in overeating.

When analyzing L (liking), WE (wanting eating) and WR (wanting resisting) scores in Study 2, in L-fat participants, the pattern was as follows: unsuccessful wanting < successful wanting < liking. This pattern followed the expectations that wanting events, which had lower perceptual intensities, could be resisted, while higher intensity wanting led to food consumption, followed by a consummatory reward which should be equal or beyond the anticipatory level to achieve a match or reward gain. H-Fat participants, however, provided a relatively low differentiation of ratings by type of event (L, WE, WR). Furthermore, we found a strong trend ($p = .052$) towards higher 'liking' scores in L-Fat participants as a group than in H-Fat participants. Also, when conducting the time series analysis, it was established that following a morning meal, the vector of 'liking' remained constant for the rest of the day in L-Fat participants whereas in the H-Fat group, 'liking' totally disappeared after the morning meal.

Based on the analysis of our findings, we constructed a model where we predicted food reward, or 'liking' scores, from demographic variables, attitudes towards food, food 'wanting' and eating event frequencies, and anticipatory ratings. Higher food reward was predicted by a lower body fat %, older age, and higher implicit attitude scores.

The findings of our study suggest that obese people gain less reward from eating. H-fat participants experienced lower reward compared to L-fat group which could imply that they have a differently functioning reward system. In other words, the reward processing in the brains of overweight and obese people might not be the same as in lean people and could be dysfunctional in some way. More specifically, our findings could suggest that in H-fat people, either the capability to select food for reward is impaired or avoided, or, alternatively, lower 'liking' scores are a sign of deficient consummatory reward perception and/or problems to bring *wanting* and *liking* perception into context, e.g. impaired food reward related learning. It has previously been recognized that there is an interaction between 'wanting' and 'liking' and one without the other does not result in a satisfactory experience (Finlayson, King, & Blundell, 2007).

H-group participants might not chose appropriate food for their anticipated reward, or the reward anticipation may be strongly influenced by acute neurobiological state (e.g. linked to hunger, craving) mismatching anticipatory and consummatory reward expectations. It has been found that expectations play an important role in the regulation of food intake of restrained eaters (Kemps et al., 2016). Enhanced craving may contribute to anticipatory reward expectations which are not based on former experience but on motivational drive from craving traits which could lead to uncoordinated response of consummatory reward ratings to levels of anticipation. This assumption is reflected in the incentive salience theory; fluctuations in motivation intensities can alter anticipatory reward expectations and therefore would lead to unadjusted consummatory reward outcomes. Several findings have been reported where physiological state and dopamine related manipulations led to alterations in wanting which were not reflected by past reward experience (Berridge 2012).

In summary, our data collected in free-living condition with a novel smart phone application could be interpreted as a strong support for reward deficiency in obese people while several observations point towards a more complex problem with involvement of enhanced craving contribution for wanting without integrating former consummatory reward information into the reward expectation. In particular, these findings might be of high value to further investigations of related hypotheses in more stringent experimental conditions.

1.1.4 Exercise and Eating Behaviour

We found that exercise created significant differences in the 'liking' and 'wanting' events for the lean and overweight groups. The 'wanting' scores in the 24 hours following exercise increased in lean individuals and decreased below baseline for overweight individuals. Exercising temporarily suppressed both the 'intense desire to eat' and the perception of 'wanting' in overweight individuals - which reduced 'meal frequency' but not the 'sum of meal duration' - while it increased 'intense desire to eat' and 'resisted wanting' in lean individuals. A study by Ledochowski, Ruedl, Taylor and Kopp (2015) also showed that in overweight people, exercise reduced the urges for sugary snacks.

Although 'wanting' was temporarily suppressed in overweight and obese individuals, craving scores came back to baseline or higher within one hour of exercise, which is also consistent with previous studies (Broom et al., 2009; King et al., 2010). Unick et al. (2015) (2015) also point out that some individuals increase their energy intake post exercise while others do not, which has led to attempts to try and distinguish between 'compensators' and non-compensators'. Study 3 showed that in overweight individuals, compensatory eating behaviour occurred following exercise, which could reduce the effectiveness of exercise interventions. Compensatory eating has previously been recognized as an important factor that could explain why some people fail to lose weight. There appears to be a connection between levels of activity and energy intake that is not always promoting weight loss. For instance, when subjects were shown action words such as 'go' and 'active' or given exercise messages, their energy intake increased (Albarracin, Wang, & Leeper, 2009). The findings about priming with exercise/action cues highlighted that exercise-promoting programs could result in unintended dietary changes. A recent study also suggested that people might be more or less influenced by priming depending on their baseline levels of exercise (Stein, Greathouse, & Otto, 2016). This might be a necessary consideration when designing an evidence-based weight-loss program. Nonetheless, voluntary exercise has been seen as an important component of total daily energy expenditure that can affect daily energy balance and help solve the obesity epidemics (Wiklund, 2016).

5.2 5.2 Strengths and Limitations

Our novel development of a smart phone application (Mind Eating) is a new approach for measuring the hedonic components of 'wanting' and 'liking'. However, in the application, the 'wanting' component captured both hedonic and homeostatic aspects of eating behaviour, so we cannot tell if the individual was 'wanting' food for specifically homeostatic or hedonic reasons just by looking at the results of the application. The results need to be interpreted in the context of other findings to evaluate if in overweight and obese individuals, hedonic mechanisms might override the homeostatic mechanisms and act independently of them as has previously been suggested (Finlayson et al., 2008a; Mela, 2006).

Another question in relation to our smartphone data collection is whether it reflects participants' real free-living eating behaviour sufficiently. As with all studies that rely on self-reporting, our study could be subjected to underreporting, which presents a methodological problem (Murakami & Livingstone, 2014). It has previously been reported that when participants are required to submit daily or itemized reports, they are more likely to cheat compared to submitting an overview report (Rilke et al., 2016). Psychologically, one-by-one reporting seems to include only small lies, which people are more prepared to make compared to adjusting a bigger report. Our participants had to enter their 'wanting' and 'liking' using the smart phone application, so data collection depended on their accurate input. Only the 'wanting' and eating they were consciously aware of was recorded in their answers. Gibbons et al. (2014) asserted that people are often not able to accurately assess their implicit 'wanting' for food. However, this component is to some degree included in responses reflecting motivations for food, which should be as spontaneous as possible to capture the core process of 'wanting'. Another consideration is that the participants might have adapted their behaviours as a result of being included in the study. A degree of self-monitoring of natural behaviour might have occurred and affected the results. Also, the scoring system used in the Mind Eating application is subjective and is measured without external calibration. Participants enter their scores that relate to unspecified food and drink intake, which makes the scores general and difficult to compare with other studies that differentiated one food from another or specific foods from non-food items.

Another limitation was that Study 3 was a pilot study, so the sample was relatively small (N=18). It consisted of individuals who were recruited via an advertising campaign at the university. The sampling method implies these individuals were motivated to participate in the study and might not be representative of the general population of lean and obese sedentary people. Furthermore, the small sample size makes generalizations of results impossible due to a big margin of error. However, this study was not meant as a full-scale study, but a mini version of a future study and could serve as a preparation for a future major study (Polit & Beck, 2006). There is not much published guidance on the size of pilot studies, but there is a general guideline of using 10% of the sample required for a full study. However, this rough guideline is often considered to be too simplistic and sometimes, procedures with just a few cases can be informative (Hertzog, 2008). Nonetheless, it has been suggested that when determining an appropriate, justifiable sample size for a pilot study, the researcher needs to consider population value, feasibility issues, adequacy of instrumentation, and statistical estimates for planning a larger study. Samples as small as 10 to 15 people per group can sometimes be sufficient, but it is recommended to include at least 25 participants per group as the lowest threshold (Hertzog, 2008). For pilot studies involving group comparisons - which describes our study - a smaller sample in the range of 10 to 20 per group would be sufficient (Kieser & Wassmer, 1996). Our pilot study failed to meet this requirement, so it might not be possible to specify meaningful group differences.

Furthermore, in Study 2, data was split in two sets based on body fat percentage according to recent recommendations (Seger et al. 2015). However, in Study 3 participants were divided into two groups based on their BMI. Different ways of grouping the participants affects the comparison of data and ideally, if the pilot study was developed into a full-scale study, it, too, should use body fat percentage as a guideline for grouping the participants.

Another limitation of our study is that we were not able to record specific information about what food the participants anticipated at each wanting event, therefore our conclusion that H-fat participants chose food that was higher in caloric value was only an assumption. However, since people were not dieting and the number of *successful wanting* events and meal duration was not recorded to be different between both groups, it is likely that the H-group participants directed their behavioural choices towards food of higher caloric load and density to maintain their weight. Moreover, in Study 3, the phone application distinguished between eating behaviours for food and drink, but it could not distinguish non-caloric drinks from caloric ones. This was particularly significant because a large component of the modern calorie intakes comes from caloric drinks (Nielsen and Popkin, 2004; Dhingra et al., 2007), and caloric drinks are thought to be a significant cause of the obesity epidemic (Brayet al., 2004; Sartor et al., 2013).

Due to time and financial limitations, we were not able to develop and test an application that would be supported on all mobile platforms. Although our application was tested only on iOS and Android operating systems, it could theoretically be supported on different smart device platforms.

5.3 Recommendations for future research

The Mind Eating application now exists in the Apple Store and could be utilised in future studies to measure the anticipatory reward responses for several behaviours including eating, smoking and addictions. Since our smartphone application transcends the limitations of the lab environment, we are now able to measure the behavioural components in real life.

Taking into consideration some of the limitations of the study, we recognize that the phone application and study design need to be developed further in order to address these. We would like the application to differentiate between the 'wanting' for hedonic reasons and the 'wanting' for homeostatic reasons. Also, future versions of the application should be able to differentiate between the 'wanting' and 'liking' of caloric and non-caloric drinks.

The pilot study's main limitation was the small sample size. Therefore, we will extend the work on the exercise pilot study and work on its statistical power, which should be improved with a much larger sample size of at least 15 participants in each group. We are interested in linking theory with practice and use this application to develop evidence-based interventions for weight-loss. In the future, hedonic assessment from the Mind Eating application could be used to guide individualized intervention. Furthermore, to be able to compare different data sets and follow the latest recommendations in obesity investigations, body fat percentage should be used in any future studies as a more preferred index for grouping subjects.

Since we recognize that eating behaviour is a complex phenomenon and that hedonic and homeostatic components can sometimes be elusive to study, we propose that some of the future studies employ a mixed-methods design, so data could be interpreted in a wider context. In mixed-methods design, qualitative and quantitative data are collected and analyzed separately, and the findings of both studies are later merged in the interpretation phase of the research (Creswell 2013). This provides for a more complete and in-depth understanding of the phenomenon under study. Also, by using both qualitative and quantitative methods, the researcher contributes to a better internal and external validity of the findings (Creswell 2013). One possibility is that in the future, our quantitative phase gets complemented with qualitative interviews with the participants. This might help explain certain trends, characteristics and anomalies that were recorded using the application, and would add the experience parameter into the analysis of the findings. In addition, it would be interesting to study the effect of gender differences on eating behaviour and add the gender component to our research on eating behaviour.

Also, more work needs to be done on the validity and reliability testing of the application which will be done in the next step of this reseach.

5.4 Implications for policy and practice

Since our studies emphasised the importance of hedonic drives in overweight and obese people and supported the hypothesis that 'wanting' and 'liking' for food reward are two separate components in the hedonic process, we should move beyond viewing obesity as a condition rooted in the homeostatic component of eating. Also, considering that many different factors are involved in food choices and characteristics of eating, we need to be cautious when making assumptions and recommendations regarding nutrition and life style.

Obesogenic environment plays an important role in eating behaviour, so environmental control could be considered as a strategy to structure and limit environmental impulses. Commercial food marketers should be encouraged to support appropriate food choices by providing responsible environmental stimulation that should be audited regularly to ensure compliance with the latest research findings.

There is limited evidence available that mobile phone technology could be effectively used for behaviour change and disease management (Free et al., 2013). At the same time, it has been recognized that modern digital technology can allow for computerized treatments that could improve the availability and accessibility of health interventions for many people around the world. Various technological forms are now available for computer-based health and behavioural treatments. Some of the most commonly used include internet sites and platforms, chat rooms, virtual reality, interactive voice response systems and different computer programs and games (Rucker, 2016). Our phone application has the potential to become an accessible tool for individuals and professionals to use when evaluating eating behaviours. On an individual level, the application provides the person with information on eating patterns and frequencies, which can give more insight into their daily behaviour. This knowledge could then be used to develop individual weight-loss interventions and personalized treatment approaches.

To facilitate the individual's reward system, it could be useful to employ approaches where highly palatable foods were eaten in a structured and balanced way throughout the day and observe any changes in eating behaviour. This would require challenging some of the prevailing assumptions regarding food choices that stipulate pleasant food is usually not good for you and is unhealthy (Mela, 2006). The food industry should strive towards producing and marketing food that would be wanted and liked and that would stimulate the hedonic aspect of eating as well as be healthy for the individual.

5.5 Conclusion

Highly controlled laboratory and questionnaire-based research found that obese and lean people exhibit differences in their 'wanting' and 'liking' responses to food. However, by creating specific environmental conditions far removed from real life scenarios, the findings of these studies have limited applicability (Blundell et al., 2005; Dykes et al., 2004). Our study set out to address this challenge and aimed to provide knowledge that could bridge the divide between real life eating behaviour and obesity interventions that are based in theory.

Continuous patterns of 'wanting' and 'liking' have not yet been investigated in real life situations; therefore, the time dimensions of perception and action in eating behaviour are not well understood. To capture these, we developed a smartphone application Mind Eating that could record time patterns, or rhythms in perception, and their intensities ('wanting' and 'liking' scores of food) and help us increase the understanding of the mechanisms of obesity and the development of efficient treatment methods. After developing and piloting the phone application (Study 1), we conducted two studies (Study 2 and Study 3) where participants were grouped according to their fat percentage (Study 2) or their BMI (Study 3) and asked to record their 'wanting' and 'liking' components. Data analysis provided new evidence in support of the theory that there is reward deficiency in obese people and that future research and practice should focus on the hedonic aspects of eating and food consumption.

By making the application publicly available, we would like to encourage its further use in research and practice that would also help us address some of the limitations of the study, including small sample size of the pilot study, and validity and reliability of the application.

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APPENDICES

Appendix 1

PRIFYSGOL BANGOR UNIVERSITY

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Participant Information sheet

Study Title: Investigating eating behaviour - patterns of liking and wanting in lean and overweight/obese people.

You are being invited to take part in a research study. Before you agree to take part it is important for you to understand why the research is being done and what it will involve. Please read the following information carefully and take time to decide whether you wish to take part, or not.

Please contact the researcher if anything is unclear or you would like more information.

Kholoud Alabduljader elpaab@bangor.ac.uk Tel: 01248388254

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What is the background of the study?

We aim to get a better understanding of peoples' eating behaviour; what drives them to eat, how much satisfaction they get out of their food, as well as what time patterns they follow for eating? These questions refer to a person's appetite, cravings and response to food cues which can be defined as "Wanting," and their satisfaction from food which is defined as "Liking" (including how the food tasted, how much it matched your expectations, how much you feel rewarded by the food, and how much satiety you feel). Our study will investigate the patterns of "Wanting" and "Liking" in females for a period of 2 weeks using a newly developed phone application. By taking part in our research study using this application and performing additional tests, consisting of taking your body weight and height, of questionnaires for craving and food choice, as well as a computer task for food attitude and a diet diary, you will help us to understand peoples' eating behaviours more thoroughly. It is anticipated that we can use the data to develop a program which helps people to control their weight in a better way than dieting.

Do I have to take part?

It is up to you to decide whether or not to participate in this valuable research program. If you do decide to participate, you will be given this information sheet to keep and be asked to sign a consent form. If you do decide to participate, you are free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

Summary

You will be asked to record a diet diary for 2 weeks, for only 3 specific days per week. Moreover, you will be provided with a Smartphone application for recording your 'wanting' and 'liking' and a user manual. You will be asked to use this application for 2 weeks. It is very important for the research program's success to use this application accurately and precisely whenever you feel 'wanting' and 'liking' of food. So if you have any questions about any of the steps in this process during this study, please contact the researcher as soon as possible.

In addition, we will measure your body weight and height, and ask you to fill out questionnaires for craving and food choice. Additionally we ask you to use a computer program for food attitude and filling in a diet diary.

Smartphone Application:

As mentioned in the previous summary, our participants will be provided with a Smartphone application. Our application is called "Mind Eating." The researcher will download this application for the participants from the Apple store for free (for iPhone users) or send it by email to be downloaded to other the devices (for the Androids users). The researcher will explain all the details about how to use this application for the participant in the pre-test session.

The participant will be asked to use this application for 2 weeks. Using this application requires very little time during the day (only a few seconds each use). This application will send your data that you entered to our online data base to be analysed by the researchers.

Diet Diary

We will give you a Food Record Sheet (FRS) where you should describe with simple accuracy and precision your daily food and beverage intake. You will be asked to keep a record of your diet for 3 specific days per week during the experiment. The 3 days of each week during the experiment are randomly chosen. How to describe the foods and drinks will be fully explained in the Food Record Sheet. The analysis of your food composition is necessary to exclude the influence of certain food items on the measurements we record. It is perfectly fine to eat whatever you wish, but be sure to note everything that you eat on your Food Record Sheet.

Food attitude task

You will be asked to undergo a computerised test for investigating your food attitudes. This will allow us to assess your cognitive response towards food. The test will last for approximately 10 minutes.

Questionnaires:

You will be asked to fill out 2 questionnaires. The first one "Explicit questionnaire" and this will allow us to assess your explicit attitude towards healthy food. The second questionnaire will be a "Craving questionnaire" it consist of two parts .This questionnaire will assess your appetite towards specific food choices. These questionnaires required 10 minute time to be filled.

What are the possible benefits of participating in this study?

By participating in this study, you have the opportunity to have a comprehensive 2-week eating behaviour analysis done with a team of researchers. Your participation in this study will also help us to understand peoples' eating behaviours for the development of new programs to help control people's body weight. In addition to the above, we will pay you £5 for your time in the pre-test. Upon completion of the study, you will be entered into a raffle to win an iPod Touch 32GB which is a value of £249. There will be one winner for this raffle.

Confidentiality

All information which is collected about you during the course of the research will be kept strictly confidential. Any data which is to leave the school for possible publications or reports will have your name and any other personal information removed so that you cannot be recognised from it. It will not be possible to identify you in any of these reports or publications.

Who is organising or funding the research?

This study has been organised by Kholoud Alabduljader (PhD student), Dr Hans-Peter Kubis (Senior Lecturer) and Dr David Markland (Senior Lecturer) from the School of Sport, Health and Exercise Sciences (SSHES) of Bangor University.

Who has reviewed the study?

This study has been reviewed by the SSHES Ethics Committee

Feedback and conduct of research

SSHES is always keen to hear the views of research participants about their experience. If you would like to give feedback, please ask your researcher to provide you with Form 6 – Participant Feedback Form – from the Ethics Guidelines Handbook. Completion of this form is optional and can be done anonymously. The completed form should be returned to Prof Andrew Lemmey, Chair, SSHES Ethics Committee, SSHES, Bangor University, Bangor LL57 2PZ. All information will be treated in a strictly confidential manner.

Complaints

If during the course of this study you feel the need to complain about how the research has been carried out, for any reason, then please contact the Head of School, Prof Tim Woodman, SSHES, Bangor University, Bangor LL57 2PZ.

Any questions?

Please ask us if you have any questions. Here are the contact details of all investigators in this study:

Kholoud Alabduljader (PhD student) pepc09@bangor.ac.uk Tel: 01248 38 8254

Dr Hans-Peter Kubis (Senior Lecturer) pes203@bangor.ac.uk Tel: 01248 38 8261

Dr David Markland (Senior Lecturer) d.a.markland@bangor.ac.uk Tel: 01248 38 3487

5.6 Appendix 2

NAME: ______________________ DATE: _________

FCQ-T

How frequently each statement "would be true for you in general" using a 6-point scale that ranged from 1 (*never*) to 6 (*always*);

	1	2	3	4	5	6
Being with someone who is eating often makes me hungry						
When I crave something, I know I won't be able to stop eating once I start						
If I eat what I am craving, I often lose control and eat too much						
I hate it when I give in to cravings						
Food cravings invariably make me think of ways to get what I want to eat						
I feel like I have food on my mind all the time						

I often feel guilty for craving certain foods						
I find myself preoccupied with food						
I eat to feel better						
Sometimes, eating makes things seem just perfect						
Thinking about my favourite foods makes my mouth water						
I crave foods when my stomach is empty						
I feel as if my body asks me for certain foods						
I get so hungry that my stomach seems like a bottomless pit						
Eating what I crave makes me feel better						
When I satisfy a craving I feel less depressed						
When I eat what I am craving I feel guilty about myself						

Whenever I have cravings, I find myself making plans to eat						
Eating calms me down						
I crave foods when I feel bored, angry, or sad						
I feel less anxious after I eat						
If I get what I am craving I cannot stop myself from eating it						
When I crave certain foods, I usually try to eat them as soon as I can						
When I eat what I crave I feel great						
I have no will power to resist my food crave						

Once I start eating, I have trouble stopping						
I can't stop thinking about eating no matter how hard I try						
I spend a lot of time thinking about whatever it is I will eat next						
If I give in to a food craving, all control is lost						
When I'm stressed out, I crave food						
I daydream about food						
Whenever I have a food craving, I keep on thinking about eating until I actually eat the food						

If I am craving something, thoughts of eating it consume me						
My emotions often make me want to eat						
Whenever I go to a buffet I end up eating more than what I needed						
It is hard for me to resist the temptation to eat appetizing foods that are in my reach						
When I am with someone who is overeating, I usually overeat too						
When I eat food, I feel comforted						

I crave foods when I'm upset						

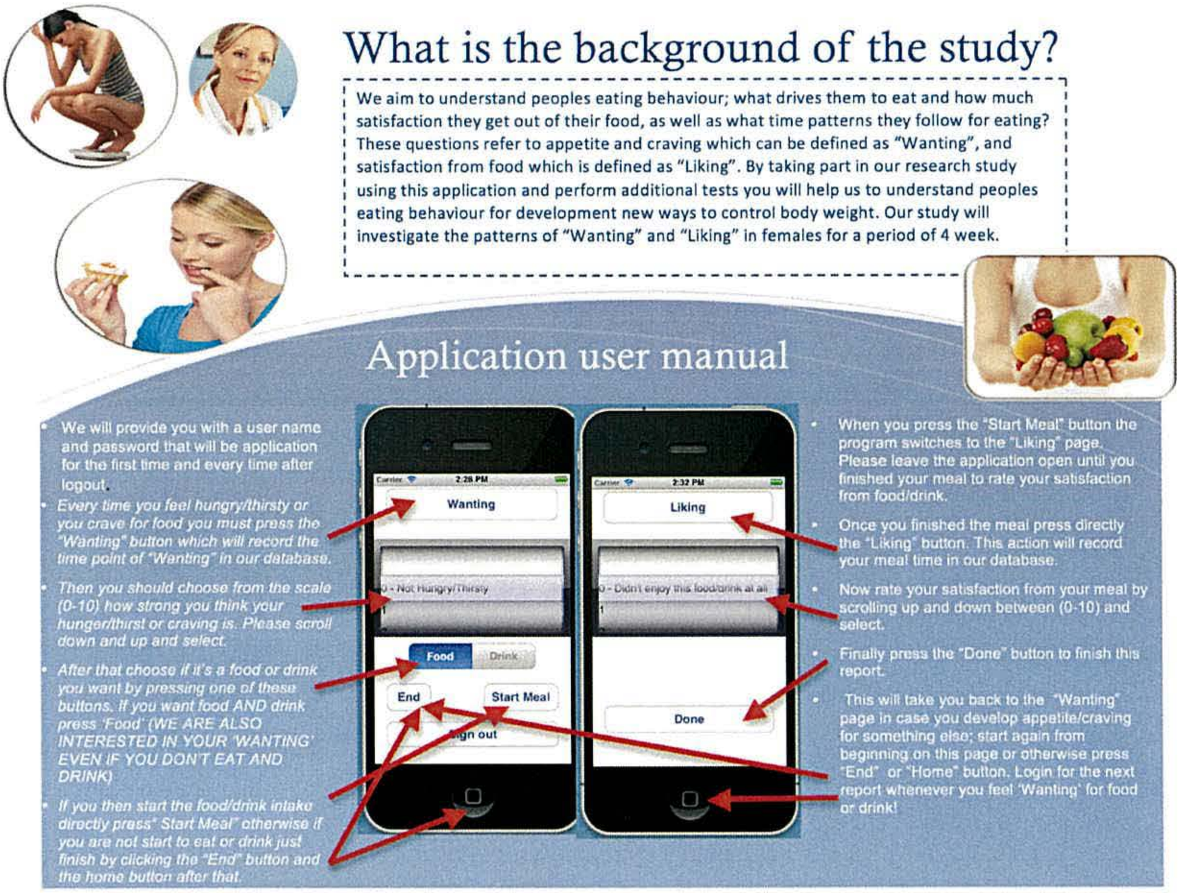
FCQ-S

Indicate the extent to which you agreed with each statement "right now, at this very moment" using a 7-point scale that ranged from 1 (*strongly agree*) to 5 (*strongly disagree*).

	1	2	3	4	5
I have an intense desire to eat something tasty					
I'm craving (one or more specific foods)					
I have an urge for (one or more specific foods)					
Eating (one or more specific foods) would make things just perfect					
If I were to eat what I'm craving, I am sure my mood would improve					
Eating (one or more specific foods) would feel wonderful					
If I ate something, I wouldn't feel so sluggish and lethargic					
Satisfying my craving would make me feel less grouchy and irritable					

I would feel more alert if I could satisfy my craving					
If I had (one or more specific foods), I could not stop eating it					
My desire to eat (one or more specific foods) seems overpowering					
I know I'm going to keep on thinking about (one or more specific foods) until I actually have it					
I am hungry					
If I ate right now, my stomach wouldn't feel as empty					
I feel weak because of not eating					

Appendex 3


What is the background of the study?
We aim to understand peoples eating behaviour; what drives them to eat and how much satisfaction they get out of their food, as well as what time patterns they follow for eating? These questions refer to appetite and craving which can be defined as "Wanting", and satisfaction from food which is defined as "Liking". By taking part in our research study using this application and perform additional tests you will help us to understand peoples eating behaviour for development new ways to control body weight. Our study will investigate the patterns of "Wanting" and "Liking" in females for a period of 4 week.
Application user manual
We will provide you with a user name and password that will be application for the first time and every time after logout.
Every time you feel hungry/thirsty or you crave for food you must press the "Wanting" button which will record the time point of "Wanting" in our database.
Then you should choose from the scale (0-10) how strong you think your hunger/thirst or craving is. Please scroll down and up and select.
After that choose if it's a food or drink you want by pressing one of these buttons. If you want food AND drink press 'Food' (WE ARE ALSO INTERESTED IN YOUR 'WANTING' EVEN IF YOU DON'T EAT AND DRINK)
If you then start the food/drink intake directly press" Start Meal" otherwise if you are not start to eat or drink just finish by clicking the "End" button and the home button after that.
Wanting
0 - Not Hungry/Thirsty
Food
Drink
End
Start Meal
Sign out
Liking
0 - Didn't enjoy this food/drink at all
Done
When you press the "Start Meal" button the program switches to the "Liking" page. Please leave the application open until you finished your meal to rate your satisfaction from food/drink.
Once you finished the meal press directly the "Liking" button. This action will record your meal time in our database.
Now rate your satisfaction from your meal by scrolling up and down between (0-10) and select.
Finally press the "Done" button to finish this report.
This will take you back to the "Wanting" page in case you develop appetite/craving for something else; start again from beginning on this page or otherwise press "End" or "Home" button. Login for the next report whenever you feel 'Wanting' for food or drink!

Points to Remember

- Always remember to press "Wanting" or "Liking" before you start to rate your hunger or satisfaction.
- You can always press "Home" button to exit the application.
- This application works with a database online, so it is a subject of hanging some times. So please if anything happened stopped you from using the application normally, please records your data on a paper and contact us as soon as you can.

Contact us

Please don't hesitate to contact us if you have any question:

Dr Hans-Peter Kubis
Kholoud Alabduljader
elpaab@bangor.ac.uk
07759893217

School of Health, Exercise and sport sciences

PRIFYSGOL BANGOR UNIVERSITY

What you need to know

Application Manual

You are being invited to take apart in our research study. It's important for you and us to understand why the research will be done and what it will involve.



What is the background of the study?

We aim to understand peoples eating behaviour; what drives them to eat and how much satisfaction they get out of their food, as well as what time patterns they follow for eating? These questions refer to appetite and craving which can be defined as "Wanting", and satisfaction from food which is defined as "Liking". By taking part in our research study using this application and perform additional tests you will help us to understand peoples eating behaviour for development new ways to control body weight. Our study will investigate the patterns of "Wanting" and "Liking" in females for a period of 4 week.

Application user manual

We will provide you with a user name and password that will be application for the first time and every time after logout.

- *Every time you feel hungry/thirsty or you crave for food you must press the "Wanting" button which will record the time point of "Wanting" in our database.*
- *Then you should choose from the scale (0-10) how strong you think your hunger/thirst or craving is. Please scroll down and up and select.*
- *After that choose if it's a food or drink you want by pressing one of these buttons. If you want food AND drink press 'Food' (WE ARE ALSO INTERESTED IN YOUR 'WANTING' EVEN IF YOU DON'T EAT AND DRINK)*
- *If you then start the food/drink intake directly press" Start Meal" otherwise if you are not start to eat or drink just finish by clicking the "End" button and the home button after that.*

- When you press the "Start Meal" button the program switches to the "Liking" page. Please leave the application open until you finished your meal to rate your satisfaction from food/drink.
- Once you finished the meal press directly the "Liking" button. This action will record your meal time in our database.
- Now rate your satisfaction from your meal by scrolling up and down between (0-10) and select.
- Finally press the "Done" button to finish this report.
- This will take you back to the "Wanting" page in case you develop appetite/craving for something else; start again from beginning on this page or otherwise press "End" or "Home" button. Login for the next report whenever you feel 'Wanting' for food or drink!

5.7 Appendix 4

FOOD PREFERENCE QUESTIONNAIRE

NAME: ___________________________ DATE: _________

On the scales below, please circle the number that best describes your feelings about **HEALTHY FOOD** **(food which rich in fibre and low in fat or sugar)**, such as vegetables, fruit, salad, brown bread, muesli, skimmed milk.

Be sure to circle just ONE number for each pair of words.

Please note that there are no right or wrong answers and no trick questions. We simply want to know how you personally feel about healthy food.

For me, eating healthy food is ……

	extremely	quite	slightly	neither	slightly	quite	extremely	
Enjoyable	1	2	3	4	5	6	7	Unenjoyably
Harmful	1	2	3	4	5	6	7	Beneficial
Useful	1	2	3	4	5	6	7	Useless
Boring	1	2	3	4	5	6	7	Interesting
Pleasant	1	2	3	4	5	6	7	Unpleasant
Stressful	1	2	3	4	5	6	7	Relaxing
Wise	1	2	3	4	5	6	7	Foolish
Bad	1	2	3	4	5	6	7	Good

5.8 Appendix 5

FORM 2 – Informed Consent to Participate in a Research Project or Experiment
(Revised 06/03/09)

Bangor University
SCHOOL OF SPORT, HEALTH AND EXERCISE SCIENCES

1	Title of project	
2	Name and e-mail address(es) of all researcher(s)	

Please tick boxes

1 I confirm that I have read and understand the Information Sheet dated .... for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2 I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, without my medical care or legal rights being affected. ☐

3 I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason. If I do decide to withdraw I understand that it will have no influence on the marks I receive, the outcome of my period of study, or my standing with my supervisor, other staff members of with the School. ☐

4 I understand that I may register any complaint I might have about this experiment with the Head of the School of Sport, Health and Exercise Sciences, and that I will be offered the opportunity of providing feedback on the experiment using the standard report forms. ☐

5 I agree to take part in the above study. ☐

Name of Participant ....

Signature .... Date ....

Name of Person taking consent...

Signature .... Date ....

WHEN COMPLETED – ONE COPY TO PARTICIPANT, ONE COPY TO RESEARCHER FILE

5.9 Appendix 6