Hedonic Hunger and Food Cue Reactivity During Weight Management

Thesis submitted in accordance with the requirements of the University of

Liverpool for the degree of Doctor of Philosophy by Bethan Rose Mead

August 2017

Declaration

No portion of this work has been submitted in support of any other

application for degree or qualification at this or any other institute of learning.

Acknowledgements

I would like to thank the University of Liverpool and Weight Watchers for giving me the opportunity and funding to undertake this Doctoral degree. In particular, I would like to thank my supervisors Emma Boyland and Amy Ahern for their limitless support, patience and encouragement over the past few years. I would also like to thank Paul Christiansen and Andy Jones for their guidance during this PhD, and Jo Harrold and Jason Halford for their support and training during my studies.

I am incredibly grateful to the wonderful friends I have made along this PhD journey. Without Lauren McGale, Moon Wilton, Pawel Jedras, Una Masic, Katie Coleman, Hannah Roberts, Danni Reaves and Maria Grimes the last few years would have been even more challenging than they were, and their support and friendship has been invaluable.

I would like to thank my friends and family for their love and support, particularly, Gaz, Mark, Laura, Bethan, Jen, Jenny and the Welshies. A special thanks goes to Mum, for the love and support, and to Cath for helping this along the way.

Last and by no means least, I thank my partner Gary Evans for his support, love, encouragement and patience over these last few years. It's been a hell of a ride.

Contents

Abbreviations

2-AG	2-arachidonyl-glycerol
AAT	Approach Avoidance Task
AB	Attentional bias
ABR	Attentional Bias Retraining
AEA	Anandamide
AN	Anorexia Nervosa
BBC	British Broadcasting Corporation
BE	Binge Eating
BED	Binge Eating Disorder
BI	Brief self-help Intervention
BMI	Body Mass Index
BN	Bulimia Nervosa
BOCF	Baseline Observation Carried Forward
CCQ	Chocolate Consumption Questionnaire
CFI	Comparative Fit Index
EEG	Electroencephalography
EU	European Union
fMRI	functional Magnetic Resonance Imaging
g	Grams
GD	Gaze Dwell
GP	General Practitioner

HC	High Calorie
Hz	Hertz
IFI	Incremental Fit Index
IST	Incentive Salience Theory
kCal	Kilocalories
kg	Kilograms
LC	Low Calorie
LOC	Loss of Control
LOCF	Last Observation Carried Forward
m2	Metres squared
MAR	Missing At Random
ms	Millisecond
NFI	Normed Fit Index
NHS	National Health Service
NICE	National Institute for Health and Clinical Excellence
PFC	Prefrontal Cortex
PFS	Power of Food Scale
PHE	Public Health England
RCT	Randomised Controlled Trial
RMSEA	Root Mean Square Error of Approximation
RT	Reaction Time
SD	Standard Deviation
SE	Standard Error

SES	Socioeconomics
SRMR	Standardised Root Mean Residual
TFEQ	Three Factor Eating Questionnaire
TLFB	Timeline Follow Back
UK	United Kingdom
US	United States
VAS	Visual Analogue Scale
WHO	World Health Organization
WOF	World Obesity Forum
WRAP	Weight-loss Referrals for Adults in Primary Care
WW	Weight Watchers
WW12	12-weeks Weight Watchers
WW52	52-weeks Weight Watchers

Abstract

Background: The constant availability and ease of access to highly palatable food has been identified as a contributor to the rising rates of obesity seen in Western countries over the past several decades. It has also been suggested that the omnipresence of food cues that characterises this environment may be driving food consumption and contributing to overweight and obesity by triggering motivation for food in the absence of an energy need. This phenomenon has been referred to as hedonic hunger. Hedonic hunger reflects the motivation for and preoccupation with palatable foods in the absence of an energy deficit. Elevated hedonic hunger has been associated with food intake and obesity. Levels of hedonic hunger appear to decrease with weight loss, but the mechanisms driving this are unclear. Hedonic hunger may also be reflective of greater sensitivity to food cues and has been proposed to be a barrier to weight loss success, although evidence to support this is lacking. By studying hedonic hunger and food cue reactivity during weight management, this thesis presents an investigation of hedonic hunger and food cue reactivity during weight management.

Key findings

Hedonic hunger reduces during weight loss (Chapter 3 and 4): Hedonic hunger decreases during the initial 12 weeks of weight loss, but this is not a result of a commercially available weight management intervention.

Hedonic hunger is stable over time (Chapter 3): Measurements of hedonic hunger taken over two years predict level of hedonic hunger at the subsequent

measurement point. This implies that hedonic hunger, or its underlying mechanism, may be relatively stable.

Changes in hedonic hunger predict future BMI (Chapter 3): Changes in hedonic hunger during the initial 12 weeks of weight loss predict BMI at 12 months. Higher hedonic hunger at the 3 months point of a weight loss trial predicted higher BMI at 12 months.

Elevated hedonic hunger is a barrier to weight loss success (Chapter 3): Participants with higher hedonic hunger who undergo 12 weeks of behavioural weight management have a higher BMI at 12 months than those with low hedonic hunger. This indicates that referral to 12 weeks of behavioural weight management is less effective in those with high hedonic hunger than low hedonic hunger.

In participants with high hedonic hunger, change in hedonic hunger is related to change in attentional bias to high calorie food cues (Chapter 4): Greater reductions in hedonic hunger were related to greater reductions in attentional bias to high calorie foods, although this is specific to individuals with high baseline hedonic hunger and is not related to weight loss.

Attentional bias retraining is not an effective way to reduce hedonic hunger, attentional bias and food consumption (Chapter 5): No effects of attentional bias retraining were seen on attentional bias, hedonic hunger or food consumption in females identified as having high hedonic hunger.

Implications: Elevated hedonic hunger represents a barrier to weight loss success. The mechanism that underlies hedonic hunger should be identified. Interventions

that reduce hedonic hunger may aid weight loss in those with high hedonic hunger,

however attentional bias retraining is not an effective way to achieve this.

List of Figures

List of Tables

Chapter 1 - Hedonic hunger and food cue reactivity during weight management: a review of the literature

1.1. Introduction

This thesis is an investigation of hedonic hunger and food cue reactivity during weight management. Rising rates of worldwide obesity are fuelling the need for effective weight management interventions; however psychological factors within an individual may impact on weight management success. Hedonic hunger and food cue reactivity are two psychological factors that may be related to weight management success. Through a series of studies, this thesis explores the concept of hedonic hunger and how this relates to food cue reactivity and weight management success in adults undergoing behavioural weight management.

This chapter presents a review of the current literature related to hedonic hunger, food cue reactivity and their relationship with weight management. This literature review begins by considering our current understanding of obesity and weight management so that the thesis topic may be understood within a wider context. A particular focus is given to external factors that influence eating behaviour and obesity. In the second half of this literature review the concepts of hedonic hunger and food cue reactivity are introduced and limitations of the current understanding of these topics are highlighted. This chapter concludes with a statement of the aims of this thesis and an overview of how these are addressed.

1.1.1. Epidemiology of Overweight and Obesity

1.1.1.1. Definition

The World Health Organisation (WHO) define overweight and obesity as "abnormal or excessive fat accumulation that may impair health" (WHO, 2017). Classification of overweight or obesity in adults is commonly based on the body mass index (BMI). The BMI calculation uses body weight in kilograms (kg) relative to height in metres squared (m^2) to provide a numerical index that can be used to ascertain which category of body mass an individual falls in to. Established cut off points for BMI categories exist (WHO, 2017) and are summarised in Table 1.1. While some propose that body fat percentage, skinfold measurement or waist circumference are more appropriate and reliable measures of weight status (Bray & Bellanger, 2006), the WHO states that BMI is "the most useful population-level measure of overweight and obesity as it is the same for both sexes and for all ages of adults" (WHO, 2017). In this thesis, I use these established BMI categories to define overweight and obesity.

Table 1.1 BMI categories and cut-off points

Classification	BMI range
Underweight	< 18.5kg/m^2
Healthy weight	18.5 kg/m^2 – 24.9 kg/m^2
Overweight	25.0 kg/m^2 – 29.9 kg/m^2
Obese	30.0 kg/m^2 – 40.0 kg/m^2
Morbidly obese	> 40 kg/m^2

1.1.1.2. Prevalence and projection estimates for obesity

Worldwide prevalence of overweight and obesity has been climbing over the past three decades, with levels of obesity more than doubling since 1980 (WHO, 2017). As of 2014 an estimated 1.9 billion adults worldwide were classed as overweight, 600 million of which were obese (WHO, 2017). Of particular relevance to this thesis, a recent report on findings from The Health Survey for England 2015 estimates 27% of men and women in England are obese, and 31% of women and 41% of men are overweight (Moody, 2016). Furthermore, the UK has the highest rate of obesity in Europe with 24.9% of UK adults having a BMI in the obese range (Food and Agriculture Organization of the United Nations, 2013).

Evidence from statistical models for weight trajectory of adults with obesity over five years shows that if an individual exceeds BMI of 35kg/m^2 their BMI is highly likely to remain in the obese range five years later, especially they develop obesity earlier in adulthood (Wong et al., 2012). Furthermore, there is evidence to suggest that early life body shape is predictive of body shape in adulthood, as having obesity in early childhood (for example, at 2 years of age), is associated with greater likelihood of having obesity as an adult (Freedman et al., 2005). Based on the rate at which levels of obesity have increased, current projections estimate that an additional 11 million more UK adults will have obesity by 2030 (Wang, McPherson, Marsh, Gortmaker, & Brown, 2011). Taken together, these projection estimates illustrate a growing need for effective prevention and reduction interventions across the lifespan.

1.1.1.3. Consequences of obesity

The World Obesity Federation (WOF) have recently described obesity as a "chronic, relapsing disease process" (Bray, Kim, & Wilding, 2017, pp.715), thus mirroring the stance of the American Medical Association (AMA; Kyle, Dhurandhar, & Allison, 2016) and WHO (James, 2008) that obesity is akin to a disease with significant health and economic consequences. These consequences will now be described in brief.

1.1.1.3.1. Impact of obesity on health

The health consequences of obesity can be considered as physical and psychological. While these undeniably interact (for example, depression risk increases if an individual has obesity, and obesity commonly occurs alongside depression; Luppino et al., (2010)), for the purposes of this chapter they will be described separately.

1.1.1.3.1.a. Impact of obesity on physical health

At least forty diseases have been identified as being exacerbated, triggered or made more likely to occur when an individual has obesity (Kaplan, 2003). Having overweight or obesity has been linked to a greater risk of developing significant, life-limiting health problems, such as cardiovascular disease, diabetes, metabolic syndrome and some cancers, and incidence of these have increased over the last several decades (WHO, 2017). For example, rates of Type 2 diabetes, a condition characterised by insulin resistance and secretion deficiencies, which in turn can lead

to cardiovascular malfunction, blindness, kidney disease and impaired quality of life (National Audit Office, 2015), have been climbing in synchrony with obesity rates. Indeed, it is estimated that 90% of UK adults with Type 2 diabetes have overweight or obesity (National Audit Office, 2015). Furthermore, having overweight or obesity has been shown to increase an individual's risk of cancers such as, ovary, cervix, breast, colon, gall bladder, kidney, pancreas, oesophagus, prostate and thyroid (Kushi et al., 2006). The impact of the consequences of obesity on physical health can also be seen in recent estimates of obesity-related deaths. It is estimated that 7.1% deaths in England and Wales in 2014 could attributed to excess weight (Tovey, 2017). The severity of the effect obesity and its comorbidities can have on physical health serves to underline the urgency of the need for effective, accessible weight management interventions.

1.1.1.3.1.b. Impact of obesity on mental health

In addition to having a negative impact on physical health, a body of evidence suggests that having overweight or obesity has a negative impact on mental health. It must be acknowledged that the relationship between obesity and mental health is undoubtedly to some extent reciprocal (Luppino et al., 2010; Singh, 2014). For example, Luppino et al (2010) showed that individuals with obesity are more likely to experience depression than healthy weight individuals, and someone with depression is in turn more likely to develop obesity than an individual without depression. However, a range of studies have indicated a higher incidence or risk of mental health issues and reduced quality of life is associated with obesity.

Evidence for the association between obesity and mental health issues is seen in studies of adults and children. In children, childhood obesity has been associated with lower self-esteem and quality of life (Griffiths, Parsons, & Hill, 2010) and emotional and behavioural difficulties have been associated with obesity in boys as young as 3 years old (Griffiths, Dezateux, & Hill, 2011). In adults, particularly females, obesity has also been associated with low self-esteem and body image dissatisfaction (Sarwer, Thompson, & Cash, 2005) and incidence of major depressive disorder (Carpenter, Hasin, Allison, & Faith, 2000). A large-scale cross-sectional study has also shown that, in adults, obesity was associated with a 25% greater likelihood of mood and anxiety disorders (Simon et al., 2006). Furthermore, after controlling for the effects of social class, social support and baseline depression levels in a longitudinal study of obesity and depression, Roberts, Deleger, Strawbridge and Kaplan (2003) demonstrated that baseline obesity was associated with a greater risk of depression five years later. A long-lasting, similar, association has been shown between obesity and mental health issues in women assessed for weight and mental health measures in 1975 and again in 2002/2003 (Kasen, Cohen, Chen, & Must, 2008). Taken together, the consistent links between obesity and emotional and mental health difficulties through childhood to adulthood show that the consequences of obesity reach beyond physical health comorbidities, thus highlighting the severity of obesity as a major public health concern.

1.1.1.3.2. Obesity stigma

Although not a primary focus of this thesis, it should be acknowledged that obesity stigma may be both a consequence of and contributor to obesity. Research shows that adults and children perceive those with obesity differently to healthy weight individuals. Puhl and Brownell (2001) described evidence for people with obesity to be perceived as lazy, undisciplined and incompetent, and such negative perceptions were found to have persisted in an updated review of obesity stigma research in 2009 (Puhl & Heuer, 2009). Mistreatment and discrimination as a result of obesity stigma is also common. Falkner et al. (1999) reported that 22% of women and 17% men in an American sample felt they had been mistreated because of their weight. More recently, estimates have suggested that 40% of individuals with a BMI greater than 35 kg/m^2 have experienced obesity-related discrimination (Puhl, Andreyeva, & Brownell, 2008).

Negative perceptions of obesity have also been shown to begin in childhood. In one study it was suggested that children and adolescents with obesity (age 8-16 years) may be less "liked" or nominated as a friend by their healthy weight peers (Zeller, Reiter-Purtill, & Ramey, 2008). In a series of studies with 4-6 year old children who read a story book where a character called "Alfie" was presented as obese or normal weight, Harrison, Rowlinson and Hill (2016) showed that young children perceived "Alfie" more negatively when he was portrayed as having obesity. When compared to a normal-weight character, children rated "Alfie" as less likely to be academically competent, to be invited to parties or chosen as their own friend.

In addition to stigma resulting from obesity, obesity stigma may be a contributing or maintaining factor for excess weight. Recent evidence suggests that exposure to weight stigmatisation may promote increased food consumption, thus perpetuating the cycle of obesity and stigma. Schvey, Puhl, and Brownell (2011) showed that women with overweight who saw a video that depicted weight stigmatising material consumed more snack food in a laboratory intake measure than healthy weight women who saw the same video, or than women with overweight and women of a healthy weight who saw a neutral video. Furthermore, a recent review has highlighted that such stigma and weight-related teasing appears to have a paradoxical effect on eating behaviours. Vartanian and Porter (2016) suggest that those who experience stigma may also experience decreased motivation to diet and are more likely to engage in unhealthy eating behaviours, such as binge eating. This highlights the potential negative impact of weight stigma on the health of a person with obesity, and that experience of stigma may contribute to their obesity.

1.1.1.3.3. Economic cost of overweight and obesity

As the incidence of obesity-related comorbidities increases, the economic cost of managing and treating them also rises. In the workplace obesity seems to be associated with enterprise costs. A review by Schmier, Jones, and Halpern (2006) suggested that obesity was associated with a greater risk of loss of productivity in the work place, and workers with obesity lost more days of work due to sickness than workers without obesity. This has been supported by a study of UK workers

that reported that workers with obesity took approximate 4 more work days off sick than those without obesity did (Harvey et al., 2010).

The UK Government has attempted to quantify the financial cost of overweight and obesity on the UK economy. The Foresight Report (Butland, Jebb, Kopelman, & Mcpherson, 2007) was produced by the UK Government Office for Science to outline the current understanding of obesity and outline proposals for tackling obesity in the UK in coming decades. The Foresight Report states that in 1998 overweight and obesity cost the NHS £479.3 million. In startling contrast, the report estimates that by 2050, the NHS will have to spend £10 billion per year on issues related to overweight and obesity, and the wider societal cost of overweight and obesity will reach £49.9 billion. It is important to note that these figures were based on UK Government data for 1993-2004, so the effects of inflation and increase in obesity rates since 2004 are not reflected in these projections. Nonetheless, the magnitude of the financial projections detailed in the Foresight Report emphasise the economic impact the rise in rates of overweight and obesity and, without effective prevention and reduction strategies, the financial pressure this will place on healthcare resources.

1.1.1.4. The aetiology of obesity

1.1.1.4.1. Energy imbalance

The cause of overweight and obesity is complex and multifaceted, being determined by an interaction between an array of psychological, genetic, environmental and economic factors. The intricate and interconnecting nature of

10

these factors is well portrayed by the "Obesity Systems Map" (Vandenbroeck, Goossens, & Clemens, 2007) that was produced as part of the Foresight Report (Butland, Jebb, Kopelman, & Mcpherson, 2007). The "Obesity Systems Map" identifies 108 factors that contribute to obesity, which are connected by over 300 links to demonstrate the interplay of multiple variables that contribute toward obesity. A copy of the "Obesity Systems Map" is shown for reference in Appendix 1.

Although the aetiology of obesity has been established as highly complex, this can be summarised as the result of energy imbalance over time. If energy intake via food and drink is greater than the amount of energy expended a positive energy balance occurs which, if persistent, leads to weight gain and ultimately overweight and obesity. Dietary reference values for adults in the UK recommend and daily energy intake of 2,000 kilocalories (kcal; 8,400kilojoules) for women and 2,500kcal (10,500kilojoules) for men (Department of Health, 1991). While the rising prevalence of overweight and obesity would imply that individuals have poor understanding of what constitutes a healthy diet, Brown et al. (2011) suggests the opposite is true. Brown et al. have shown that many consumers do have an awareness of what a healthy diet is and intend to eat healthily. This disparity between proposed nutritional knowledge and rising rates of obesity highlights the complexity of the aetiology of obesity. Indeed, Jebb (1997) described obesity as a result of genetic, psychosocial and environmental factors that interact via energy intake and expenditure. These factors will now be briefly described.

1.1.1.4.2. Genetic factors

The past several decades have produced a growing body of literature that has identified evidence for the heritability of the susceptibility to developing overweight or obesity. Adoption studies, where adopted offspring are compared to their biological relatives, provide evidence for the role of genetics in obesity as they allow for separation of the effect of genetics versus the adoptive home environment on the offspring's characteristics. If an adopted individual is more similar to their biological parents than they are to their adopted parents for a certain trait or factor (e.g. obesity), it can be proposed that the genetic similarity between offspring and the biological parents contributes to the expression of the trait or factor in the offspring to a greater degree than the shared environment of the adoptive family.

Results from studies using the Danish Adoption Register (Petersen & Sørensen, 2011a, 2011b) showed that the BMI of adoptees was more closely related to that of their biological parents, particularly mothers, than their adoptive parents, leading authors to conclude that BMI was heavily influenced by genetic factors (Sørensen & Stunkard, 1993; Stunkard et al., 1986). Furthermore, a classic study by Bouchard, Pérusse, Leblanc, Tremblay and Thériault (1988) assessed the heritability of obesity within family members and indicated that correlation factors of BMI were approximately 0.2 for parent-offspring pairs and 0.25 between siblings. While these results imply there is some level of genetic influence on obesity, large amounts of variation in BMI between family members cannot be accounted for by genetic similarity alone, and nongenetic factors must influence obesity.

Technological advances have aided further exploration of genetic influences on obesity. Research has shown that the heritability of risk for obesity may act through genetic influence on specific factors involved in food intake and energy expenditure (Shawky & Sadik, 2012). Discussion of individual factors is beyond the scope of this thesis, but briefly they include: congenital deficiencies in appetitive hormone encoding/related receptors (e.g. leptin; Farooqi, 2005), differences in b-adrenoceptor gene families (Shawky & Sadik, 2012) and mutations to genes related to taste preference (Kim et al., 2003). A review by Choquet and Meyre (2011) identified that, at the time, 67 loci of candidate genes involved in obesity were known and that genes interact with the environment to influence weight management treatment response in some individuals. Indeed, genetics cannot explain all inter-individual variability in obesity, but it would appear that some genetic factors can interact with environmental factors to increase one's risk of developing obesity.

1.1.1.4.3. Socioeconomic factors

Socioeconomic Status (SES) reflects the social and economic status of an individual or group and is assessed by a combination of education, income and occupation (Baker, 2014). Lower SES reflects lower income, fewer years in formal education and lower status occupation. SES has been linked to health outcomes, with the risk of experiencing health problems being higher in those of lower SES (Adler & Ostrove, 1999). Of most relevance to this thesis, higher rates of obesity have also been associated with lower SES, suggesting that lower SES poses a risk factor for excess

weight (Ball & Crawford, 2005; McLaren, 2007; Sobal & Stunkard, 1989). Explanations for this association are often lacking (Ball & Crawford, 2005), but these findings may be indicative of disparities in access to healthy food (Sooman, Macintyre, & Anderson, 1993) and nutritional knowledge (Parmenter, Waller, & Wardle, 2000) between those of low and higher SES. Further evidence for such a disparity comes from studies of an individual's ability to recognise obesity. Wardle and Griffith (2001) and Johnston and Lordan (2014) report that higher SES individuals are more likely to recognise if they have overweight, thus enabling them to attempt weight loss, than lower SES individuals.

Discussion of environmental factors that influence obesity refers to the way the current environment passively encourages obesity to develop. Highly palatable, affordable food is increasingly widely available and typically energy-dense (containing large numbers of kcals per gram). For example, in some parts of the UK it has been reported that the number of fast food outlets has risen by 45% from 1990-2008 (Maguire, Burgoine, & Monsivais, 2015), representing a growing trend for increased availability of unhealthy foods. In particular, the prevalence and options for obtaining unhealthy food combined with the lack of access to healthier food options has resulted in some urban environments being labelled as "food deserts". "Food deserts" refers to areas characterised by a paucity of access to affordable, healthy food and an abundance of nutritionally poor food options (Wrigley, 2002). The consequences of this for general health inequalities have been shown by research that has demonstrated an association between exposure to fast food outlets and obesity. Burgoine, Forouhi, Griffin, Wareham and Monsivais (2014) have

shown that increased exposure to fast food outlets is more common in economically deprived areas and is associated with a higher risk of obesity.

An additional environmental factor that contributes to obesity is the way our environment discourages opportunities for physical activity. Such opportunities decrease when our environment makes sedentary activity more accessible (Jones, Bentham, Foster, Hillsdon, & Panter, 2007). This is common to many Western, urban environments. An example of this would be the prevalence of mechanical escalators and limited staircases in shopping centres. This has been attributed to urban planning (Lake & Townshend, 2006). The combination of reduced opportunity for physical activity and the abundance of convenient, unhealthy foods have been proposed as environmental contributors to the prevalence of obesity (Elinder & Jansson, 2008). Environmental factors that influence obesity and weight management are highly relevant to this thesis and are explored in more detail in section 1.3.

1.2. Weight management

The rising rate of obesity seen in recent decades (WHO, 2017) has fuelled demand for preventative action and efficacious, cost-effective and scalable weight management options (Bray et al., 2017). This demand is reflected by the prevalence of weight management attempts in the general population. It has been estimated that as many as 42% of adults have attempted to lose weight in the past year (Santos, Sniehotta, Marques, Carraça, & Teixeira, 2017).

In the UK, NICE (National Institute for Health and Clinical Excellence) guidelines state that a range of treatment options should be discussed with patients, including pharmacological, surgical and behavioural weight management options (NICE, 2014). These treatment options, NICE recommendations and relevant related literature will now be described.

1.2.1. Pharmacological weight management

Pharmacological interventions for obesity aim to regulate food intake and facilitate weight loss. The precise mechanism of action varies between types of anti-obesity drug, but the effects of many drugs are typically achieved by increasing dietary thermogenesis (energy expenditure during food metabolism), suppressing fat absorption or dampening appetitive drives (Li & Cheung, 2009). Some treatments, when used in conjunction with lifestyle changes, have shown success in weight reduction (Yanovski & Yanovski, 2014), however concerns over the safety and side effects of pharmacological obesity treatments have been raised and have resulted in some treatments (e.g. Sibutramine) being withdrawn from use (Cheung, Cheung, & Samaranayake, 2013).

Questions have also been raised about the lack of consideration given to psychological determinants of eating behaviour in research on pharmacological obesity treatments. Despite the clear role for sensitivity to palatable food in the development of obesity, psychological underpinnings of obesogenic eating behaviours are often overlooked during drug generation (Halford, Boyland, Blundell, Kirkham, & Harrold, 2010). This is also evident in the limited understanding of how such pharmacological obesity treatments act upon neural and psychological drivers

of maladaptive eating behaviour (Roberts, Christiansen, & Halford, 2017). This problem is not unique to pharmacological obesity management interventions and is discussed in Section 1.5.4.

Despite the conflicting evidence surrounding the use, effectiveness and safety of pharmacological interventions for obesity they are still considered among treatment options for managing excess weight in some adults. Evidence shows that they are effective in producing short-term weight losses over approximately six months, although weight loss maintenance is often problematic (Hainer, Toplak, & Mitrakou, 2008). In the UK, NICE recommend that drug treatments are considered when an individual's weight loss has stalled or they have failed to lose or maintain weight loss through physical activity, dietary or behaviour change efforts (NICE, 2014). The primary pharmacological treatment prescribed in the UK is Orlistat, which is recommended for use in individuals with a BMI greater than 28kg/m^2 who are also at risk of co-morbidities such as type 2 diabetes (NICE, 2017).

1.2.2. Bariatric surgery

"Bariatric surgery" refers to a range of invasive surgical interventions designed to reduce weight by restricting food intake and/or promoting food malabsorption (Rubino, 2013). Detailed discussion of the types of bariatric surgery procedures and efficacy of individual intervention types is beyond the focus of this thesis but an overview of bariatric surgery for weight loss is presented here. This is relevant to the studies discussed in Chapter 3 and Chapter 4, and research related to

hedonic hunger in patients who have undergone bariatric surgery is discussed in section 1.5.2 of this literature review.

Development of surgical interventions for obesity began in the 1950's with observations that surgically-induced malabsorption resulting from shortening of the intestine produced massive weight loss (Buchwald & Buchwald, 2002). Multiple types of surgical procedures have been established over the past sixty years (Celio & Pories, 2016) and, although the precise operative methods differ, all procedures aim to produce large weight losses in individuals with severe obesity. Generally, modern surgical interventions can be categorised as *malabsorptive*, *restrictive* or *mixed* procedures (Celio & Pories, 2016). *Malabsorptive* procedures (e.g. jejunoileal bypass) restrict food absorption by shortening the small intestine; *restrictive* procedures (e.g. gastric banding) dramatically reduce the size of the stomach, limiting the amount of food it can hold; *mixed* procedures (e.g. gastric bypass surgery) both severely reduce stomach size and circumvent part of the small intestine to limit both the amount of food consumed and absorbed.

In the UK, NICE recommend that adults are referred for bariatric surgery if they have a BMI over 40 kg/m^2 and have not achieved or maintained significant weight loss through nonsurgical measures, or if they have a BMI of 35-40 kg/m^2 alongside other substantial health concerns that may be improved by weight loss, such as type-2 diabetes (NICE, 2016). Evidence shows that bariatric surgery is a cost effective (Salem, Jensen, & Flum, 2005) and highly effective treatment for obesity that produces significant long-term weight loss and reduced obesity-related mortality (Sjöström et al., 2007). Bariatric surgery is the most favourable treatment for severe obesity (Pories, 2008), and the number of recorded operations performed

worldwide has increased in line with rising obesity rates over the ten years from 2003 to 2013 from 146,301 (Buchwald & Williams, 2004) to 468,609 (Angrisani et al., 2015).

1.2.3. Behavioural weight management

Behavioural weight management is recommended by NICE for weight management within primary care (NICE, 2014). Behavioural weight management programmes incorporate diet and exercise guidance to promote weight loss and encourage participants to adopt lifestyle changes to facilitate this. However, rising rates of obesity place strain on healthcare resources for providing NHS-led care on the required scale, and UK government recommendations have identified that standard treatment options delivered through primary care settings cannot be delivered at a sufficient scale to produce meaningful weight changes at a population level (Swanton, 2008). In response to this, healthcare guidelines recommend that referral to commercial behavioural weight loss programmes should be considered and discussed with patients (NICE, 2014).

1.2.3.1. Evidence for the effectiveness of commercial behavioural weight management programmes

Evidence for the effectiveness of commercial behavioural weight management programmes suggests that they produce beneficial weight loss effects. In a large-scale review of the effectiveness of referral to commercial weight loss providers, Hartmann-Boyce et al. (2014) showed that behavioural weight management delivered via commercial weight management groups in community

settings was effective in producing weight loss. Results showed that participants who underwent commercial weight management lost approximately 2.2kg more weight over 12 months than participants undergoing standard treatment in a primary care setting. Hartmann-Boyce et al. (2014) conclude that there was no evidence that standard treatment delivered in a primary care setting produced meaningful weight loss.

Two of the most commonly referred to commercial weight management programmes are Weight Watchers (Weight Watchers, n.d.b) and Slimming World (Slimming World, n.d.), both of which are highly popular commercial weight management programmes. In both of these programmes, participants (referred to by programmes as "members") follow the dietary guidelines set by the programme and attend weekly group support "meetings" with other members, led by a company representative. Both programmes also provide access to online resources to help members manage their dietary allowances. Weight Watchers is one of the most widely used weight management programmes globally (Weight Watchers, 2016), with over 6000 weekly meetings available in the UK (Weight Watchers, 2017a). Slimming World is also highly popular, with an estimated 16,000 weekly UK meetings occurring (Slimming World, n.d.).

An early study of referral to commercial weight loss providers is described by Lavin et al. (2006). This study assessed the feasibility of referral to Slimming World for 12 weeks from a primary healthcare provider in the UK. Results showed that the intervention was feasible, with participants accepting the intervention and some choosing to continue attending Slimming World of their own accord after the 12

week referral had ended. Weight loss outcomes were also positive; average weight loss was 5.4kg, representing 6.4% of baseline weight. NICE recommend that weight loss of ≥5% baseline weight can produce clinically significant benefits (NICE, 2015), so the weight loss reported in this study was clinically significant.

Primary care referral to commercial weight loss programmes has become more common since the publication of Lavin et al. (2006), as is reported by Stubbs, Pallister, Whybrow, Avery and Lavin (2011). In a large-scale assessment of the effectiveness of primary care referral to Slimming World, Stubbs et al. (2011) reported that such referrals are practical and effective. Their study analysed data from 34,271 participants who had been referred by their healthcare provider to Slimming World for 12 weeks. Results showed that participants lost an average of 4% of baseline weight, however analyses that included only participants who attended at least 10 of the 12 weeks of the intervention showed that participants lost an average 5.5% of baseline weight, suggesting that referral to the commercial weight loss programme was effective in producing clinically significant weight loss.

The two studies described above provide support for referral to commercial weight loss programmes, although they both report findings from referral to Slimming World. In addition to Slimming World, the NHS offers referral to Weight Watchers as a commercial weight loss programme (Weight Watchers, n.d.). Evidence from trials and a review that compare weight loss outcomes between different commercial weight loss programmes has suggested that Weight Watchers may be the most effective referral option (Gudzune et al., 2015; Jebb et al., 2011; Jolly et al., 2011). This research is described below.

1.2.3.2. Evidence for the effectiveness of referral to Weight Watchers

The Weight Watchers programme provides guidance on nutritional balance and physical activity and encourages members to adopt lifestyle habits to support this. Weekly group meetings take place in community venues and are organised by a group "leader" who is typically a lay-person trained by Weight Watchers in programme delivery and support. Weight Watchers is commercially available to the general public for a weekly fee. The NHS also operates a referral system whereby primary care providers can refer patients to Weight Watchers at no cost to the patient. Referral is typically for 12 weeks (Weight Watchers, n.d.).

Analysis of data from 29,326 participants in the Weight Watchers NHS referral scheme shows that referral to Weight Watchers produces clinically beneficial weight loss. Ahern, Olson, Aston and Jebb (2011) reported that participants who were referred to Weight Watchers for 12 weeks achieved an average 2.8kg weight loss during the intervention. Data also showed that a third of participants who began the intervention (attended at least one Weight Watchers meeting) lost ≥ 5% of initial baseline weight. The authors concluded that weight loss achieved by NHS referral to Weight Watchers was comparable to other primary care interventions, and referral to Weight Watchers could be a scalable and effective means of producing weight loss in primary care.

Although findings from Ahern et al. (2011) show support for the effectiveness of referral to Weight Watchers, data were not compared to other commercial weight loss programmes so the superiority of Weight Watchers as a

referral option cannot be assumed. However, other reports have compared the effects of Weight Watchers to other commercial weight loss programmes. Jolly et al. (2011) compared the effectiveness of a 12 week referral to Weight Watchers, Slimming World and Rosemary Conley (another form of commercial weight loss programme) to 3 types of standard care (dietetics led programme, general practice counselling or pharmacy-led counselling). Participants were 740 adults with overweight or obesity who resided in the UK. Intervention allocation was not randomised; participants were able to choose their preferred intervention assignment. All interventions except general practice and pharmacy-led counselling showed significant weight loss at the end of the 12 week intervention, but Weight Watchers was the only intervention to show significantly greater weight loss than standard care at one year, and a third of participants in the Weight Watchers intervention showed clinically significant weight loss of ≥5% of baseline weight at one year.

Further support for the effectiveness of referral to Weight Watchers comes from Madigan, Daley, Lewis, Jolly and Aveyard (2014), who conducted a non-inferiority analysis to assess which weight loss programmes are as effective as Weight Watchers. Analysis of weight loss in participants referred to 1 of 3 commercial weight loss programmes (Weight Watchers, Slimming World or Rosemary Conley) or a NHS group programme (standard care) for 12 weeks showed that referral to a commercial weight loss provider resulted in greater weight loss than standard care, and weight losses from Slimming World and Rosemary Conley were not inferior to Weight Watchers at 3 months. This implies that the three

commercial providers were as effective as each other, and all were more effective than standard care. Participants were followed up at 12 months and the same pattern of results was observed. These findings support the use of referral to Weight Watchers, Slimming World and Rosemary Conley for weight loss.

More recent evidence for the effectiveness of referral to Weight Watchers comes from a systematic review of the efficacy of popular weight loss programmes (Gudzune et al., 2015). This review considered data from 45 studies that evaluated weight loss from Weight Watchers, low-calorie meal replacement programmes and commercially available meal plans. Synthesis of data showed that Weight Watchers and the "Jenny Craig meal replacement programme" produced the most weight loss at 12 months. Weight Watchers participants achieved at 2.6% greater weight loss than control/standard care interventions; participants following the Jenny Craig programme lost at least 4.9% more weight than participants following control programmes. This review highlights that these two interventions should be considered as potential options for referral programmes in healthcare settings, and provides supporting evidence for the use of referrals to Weight Watchers in the UK.

1.2.3.3. Limitations of evidence supporting referral to commercial weight loss programmes

There is a growing body of evidence that demonstrates the effectiveness of referral to commercial behavioural weight management programmes; however all of the studies cited here have a common limitation. Kremers et al. (2010), in a review of 46 weight management studies highlighted that while studies report the

effectiveness of interventions, few, if any, speculate on or assess the mechanisms that underlie the behavioural changes observed. One aim of the current thesis was to explore the relationship between hedonic hunger and BMI during weight loss (Chapter 3 and 4) in an attempt to address this criticism and explore such potential behavioural changes.

The studies described in sections 1.2.1.1 – 1.2.1.2 provide convincing support for the use of commercial behavioural weight loss programmes in primary care, particularly Weight Watchers, however there are a number of limitations to these studies that should be acknowledged. Firstly, as commented by Gudzune et al., (2015), much of the evidence supporting the use of these interventions is based on short intervention lengths or follow-up times, often less than 12 months. This limits the inferences that can be made when healthcare professionals (or patients) are deciding on treatment options for patients.

Limited follow-up time in weight loss trials is unlikely to provide an accurate estimate of the effects of an intervention in the longer term. There is ample evidence to support the use of Weight Watchers and other behavioural weight management programmes to achieve weight loss over initial referral periods, and even at one year (Ahern et al., 2011; Jolly et al., 2011; Madigan et al., 2014). What is lacking, however, is data for longer-term effects, such as how interventions perform when weight regain is considered. Consistent estimates for how likely weight loss is maintained are limited, although some suggest that approximately 20% of people who lose ≥ 10% of their initial weight are successful in maintaining this 5 years later (Wing & Phelan, 2005), and that weight regain may begin within 6 months of an

intervention end (Wing, 2002). Of more relevance to this thesis, Lowe, Kral and Miller-Kovach (2008) surveyed Weight Watchers members who had achieved their target weight loss 1-, 2- or 5- years previously. Participants retrospectively self-reported their weight as they recalled it at 1, 2, or 5 years after they met their target weight loss. Results showed that 78%, 71% and 50% of participants maintained at least 5% of their weight loss at 1-, 2- and 5-years respectively. Such patterns of weight regain are not detected in the short-term evaluations of behavioural weight management interventions described above, which indicates that longer-term evaluations of weight loss interventions are needed to ascertain their effectiveness in producing maintained weight loss. Chapter 3 of this thesis seeks to (at least partly) address this criticism of previous work by exploring the relationship between hedonic hunger and BMI during a 2-year weight management trial

1.3. The obesogenic environment and the effect of food availability on eating behaviour

The environment in most Westernised countries has been labelled "obesogenic" because of the way it facilitates the rise of obesity (Swinburn et al., 2011). The obesogenic environment is an environment that passively encourages the development of obesity due to an abundance of easily accessible, highly palatable foods and reduced opportunities for physical activity (Swinburn, Egger, & Raza, 1999). Highly palatable, typically unhealthy food is easily available and heavily marketed (Vukmirovic, 2015), and research shows that the availability of food drives intake. For example, Wansink, Painter and Lee (2006) demonstrated that food intake

is greater when a food is visible and physically close, compared to when food is further away and less visible. Furthermore, it has been suggested that we are often unaware of the effects the external environment has on our eating behaviour, which may be problematic during weight loss when food choices need to be more consciously controlled (Vartanian, Herman, & Wansink, 2008).

The abundance of palatable food that characterises obesogenic environments has been suggested to drive food intake in excess of energy needs. Evidence for this comes from animal and human studies that have shown increases in food intake in response to food exposure. For example, a study of rats given access to either four or one feeding tubes dispensing sucrose water demonstrated the effects of the availability of food on intake (Tordoff, 2002). Over 30 days, rats with access to four feeding tubes consumed significantly more sucrose water and gained more weight than rats with access to one feeding tube, suggesting that the rats' feeding behaviour was driven to the availability of food.

Evidence that the availability of palatable food drives eating behaviour in humans can be seen in work which has measured reactions to repeated exposure to such foods. Temple and Epstein (2012) have demonstrated that repeated exposure to large quantities of palatable, unhealthy food leads to a heightened sensitivity to these foods, and it follows that the reinforcing value of these foods is related to BMI. The reinforcing value of food can be understood as how hard an individual is motivated to work to obtain food (Epstein & Leddy, 2006). In their study, Temple and Epstein used experimentally measured food reinforcement (task responses made to earn food versus responses made to earn reading time) as an analogue of

motivation for food and found that a higher BMI and motivation to eat predicted the strength of the sensitisation to food. In terms of the obesogenic environment, this implies that the constant bombardment from cues that represent palatable food may alter an individual's responses to such cues, in that they become sensitised to the cues, and this drives an increased motivation to eat such foods.

Despite evidence to suggest that the obesogenic environment influences eating behaviour, there are substantial individual differences in body weight within the general population. Some individuals maintain a healthy weight in obesogenic environments, whereas others appear to be more susceptible to excess weight. The explanations for this are complex, as they likely reflect the multifaceted aetiology of obesity (outlined in Section 1.1.4). This has generated discussion around how it may be possible to identify or characterise differences between individuals who are susceptible to the effects of the obesogenic environment and develop obesity, versus those who do not and maintain a healthy weight. Blundell and colleagues (Blundell et al., 2010; Blundell et al., 2005; Blundell & Finlayson, 2004) have proposed that such differences may represent phenotypes which can be identified by specific markers.

Blundell et al. (2005) have examined individual differences in response to a high fat diet in males who gained or maintained weight. They propose that whether or not weight gain or maintenance occurred in response to a high fat diet may be attributed to a constellation of characteristics which, together, represent a particular phenotype for likelihood of weight gain. Characteristics identified were a weak satiety response to fatty meals, a maintained preference for high-fat over low-

energy foods in the post-ingestive satiety period, a strong hedonic attraction to palatable foods and to eating, and high scores on the TFEQ (Three Factor Eating Questionnaire; Stunkard & Messick, 1985) factors of disinhibition and hunger. The clustering of individual differences in these characteristics have since been proposed to reflect obese-susceptible and obese-resistant phenotypes (Blundell et al., 2010). Blundell et al. (2010) propose that in an obesogenic environment the characteristics that form the obese-susceptible phenotype would underlie and promote excessive food intake. Specifically, this phenotype would be expressed as:

- A tendency for large meals due to a defective satiation response, meaning ineffective hunger and fullness signalling during eating

- Regularly repeated and rapidly reinitiated eating episodes, reflecting poor postprandial satiety

- Tendency to engage in binge eating episodes (reflecting defective satiation and satiety responses)

- Tendency to seek out foods with high energy density

- Increased sensitivity to hedonic (pleasurable) aspects of eating

These characteristics reflect a common tendency towards appetitive motivations, which Blundell et al. (2010, pp.233) refer to as "willingness to eat". The final two characteristics identified by Blundell et al. (2010), tendency to seek out foods with high energy density and sensitivity to hedonic aspects of eating, are of particular relevance to the this thesis. In line with suggestions that the omnipresence of food in obesogenic environments influences eating behaviour, animal models have shown that it is also the *palatability* of foods that may drive overconsumption.

Barbano and Cador (2005) demonstrated that sated rats still consumed large amounts of a palatable food (chocolate cereal) and also displayed evidence of working as hard (measured as speed in a running task) as hungry rats to obtain such food. The combination of the influence of the increased palatability and availability of foods that characterise the obesogenic environment may have on eating behaviours has led some to propose this produces "hedonic hunger" (Lowe & Butryn, 2007). Lowe and Butryn (2007) propose that hedonic hunger is distinct from homeostatic hunger in that it reflects a preoccupation with, and motivation for palatable foods in the absence of an energy deficit. Hedonic hunger and its relationship with food cue reactivity during weight management is the central focus of this thesis. Accordingly, Section 1.4 describes the concept of hedonic hunger and related evidence in detail.

1.4. Hedonic Hunger

Before reviewing the current literature surrounding the concept of hedonic hunger it is necessary to place this evidence in context. Therefore, this section begins with an overview of homeostatic hunger and its relationship with hedonic drivers of appetite. Evidence to suggest the distinction between homeostatic and hedonic hunger is presented, the hedonic hunger is introduced and described.

1.4.1. Homeostatic and hedonic hunger

Homeostatic hunger is driven by physiological feedback loops between the gut and the brain which signal the need to replenish energy stores through the ingestion of food (Harrold, Dovey, Blundell, & Halford, 2012; Murphy & Bloom,

2006). Circulating metabolic signals, such as blood nutrient levels and satiety hormones, trigger the initiation and termination of food intake via communication with the hypothalamus and brain stem (Ahima & Antwi, 2008). However, it has been remarked that homeostatic hunger signals are not the only drivers are food intake (Berthoud, 2004; Lowe & Levine, 2005; Temple, 2013), and in fact subjective measures of hunger have been shown to be a poor indicator of actual food consumption (Mattes, 1990). Hedonic drivers of appetite are capable of overriding homeostatic signals of fullness (Harrold et al., 2012), and palatability of food is a key diver of consumption beyond homeostatic need (Yeomans, Blundell, & Leshem, 2004). Indeed, it has been suggested that considering the easy availability of food in modern environments, much of the food intake that occurs is driven by anticipation of pleasurable (hedonic) aspects of food consumption (Pinel, Assanand, & Lehman, 2000). Thus, Lowe and Levine (2005) proposed a dual-factor model of obesity, whereby food intake is driven by both homeostatic and hedonic factors which act both independently and in combination. This distinction between homeostatic and hedonic regulation of food intake has been supported in the literature (Lutter & Nestler, 2009), with evidence showing distinct patterns of neural activity related to hedonic versus homeostatic hunger. For example, evidence reviewed by Berthoud (2011) distinguishes that while homeostatic hunger is managed by brain stem and hypothalamic neural activation, hedonic appetitive motivations appear to related to cortico-limbic activity (Berthoud, 2011; Goldstone et al., 2009), although it should be noted that homeostatic and hedonic factors interact in influencing eating behaviour (Berthoud, 2011).

1.4.2. Defining hedonic hunger

Lowe and Butryn (2007) define hedonic hunger as a preoccupation with, or motivation for palatable food in the absence of an energy deficit. Thoughts, feelings and urges about food may still be experienced even though food is not required for caloric need. Hedonic hunger may or may not be triggered by exposure to food-related cues, but does not occur as a result of an extended energy deficit (as this would represent homeostatic hunger). Importantly, Lowe and Butryn highlight that hedonic hunger is reflective of *motivations for* palatable food, but not *consumption of* such foods. Furthermore, Lowe and Burtyn (2007) contextualise hedonic hunger as a phenomenon driven by the obesogenic environment as a response to the constant availability and frequent consumption of highly palatable foods.

1.4.3. Measurement of hedonic hunger

Hedonic hunger can be measured using the Power of Food Scale (PFS; Cappelleri et al., 2009; Lowe et al., 2009; Lowe & Butryn, 2007). This is a validated self-report measure assessing the effects of the food environment on motivation to consume palatable food. The items of the PFS were selected from a pool of statements generated by a group of 50 women with obesity who were participating in an obesity treatment study (Cappelleri et al., 2009). Further refinement of the scale and confirmation of its factor structure was carried out in a sample of 1741 patients with obesity recruited to a clinical trial, and 1275 participants taking part in a web-based survey, revealing a 3 factor structure that yielded 3 subscales and a mean total score based on 15 items. Items describe appetite for, but not actual

consumption of, palatable food at three levels of proximity – food availability in the wider environment, food that is physically present, and food that is tasted but not yet consumed. These yield scores for three subscales related to the levels of food proximity and a total score. The PFS exhibits good reliability (α=.91) and four-month test-retest reliability in an adult population (Lowe et al, 2009). The PFS total score represents an indication of hedonic hunger, with greater scores reflecting higher hedonic hunger (Cappelleri et al., 2009; Lowe et al., 2009; Lowe & Butryn, 2007). Use of the PFS total score alone to describe hedonic hunger is common in the literature discussed throughout Section 1.5 and this thesis. Accordingly, the studies described in this thesis also use the PFS total score as measurement of hedonic hunger.

The PFS has been adapted for use in Portuguese populations by Ribeiro et al. (2015). Ribeiro et al. tested the factor structure of a translated version of the PFS in 1266 participants from the general public, a student population, and a clinical sample of patients with severe obesity who were awaiting weight loss surgery. Results validated the factor structure proposed by Lowe et al. (2009) and Cappelleri et al. (2009), indicating that the translated PFS is a valid tool for measuring hedonic hunger in Portuguese-speaking populations.

In addition to developing a translated version of the PFS, Ribeiro et al. (2015) provided the first suggested population norms for PFS scores. Based on their data from nonclinical and clinical test samples, Ribeiro et al. proposed a normed PFS total score of 2.26 for nonclinical samples and 2.52 for clinical samples. The norm for the clinical sample represents scores at the 80th percentile of the population sample, reflecting a possible distinction in levels of hedonic hunger between participants

with severe obesity and members of the general population. However, these norm values are not applied to data in the current thesis because, to date, no evidence has been published to show that norms from the Portuguese population and participants with severe obesity who are awaiting weight loss surgery are applicable to UK adults undergoing behavioural weight management, such as those who are studied in this thesis.

The PFS has also been adapted for use in children and adolescents. The Children's PFS (C-PFS) was developed by Laurent (2015) and validated by Mitchell, Cushing, and Amaro (2016). Laurent, (2015) administered the C-PFS to 48 children aged 8-13 and found that the factor structure of the C-PFS matched the PFS and determined that the C-PFS had good psychometric properties. Mitchell et al. (2016) further validated the C-PFS in a sample of 148 adolescents aged 11-18 and confirmed the factor structure and validity proposed by Laurent. The C-PFS appears to be a suitable measure of hedonic hunger in children and adolescents.

1.4.3.1. Caveats of measurement of hedonic hunger

In an initial description of hedonic hunger and the PFS, it was specified that measurements of hedonic hunger should not be taken under conditions of extreme deprivation-based homeostatic hunger, or in food-impoverished environments, because the PFS is most suitable for use in settings where food availability and access is abundant (Lowe & Butryn, 2007). This assertion implies that fasting (either deliberate or from famine) could invalidate the results of the PFS, perhaps because in these situations a participant's responses may reflect homeostatic, rather than

hedonic, hunger. What is less clear, however, is how fasting for short periods of time, such as may be required before medical examinations or attending a research study, may affect PFS scores. This is an important query to address, as many appetite-related research studies may require participants to abstain from eating for a certain amount of time prior to attending study sessions.

Witt, Raggio, Butryn, and Lowe (2014) assessed the effect of a 4 hour fast and food exposure on PFS scores in a sample of 67 healthy weight undergraduate students. A 4 hour fast was chosen as this approximates time between meals in a day (Witt et al., 2014). Their study required participants to consume a meal 4 hours before attending the laboratory. At the laboratory, half of the participants were provided with a meal replacement drink to induce a fed state and half remained fasted. Participants then completed the PFS in either the presence or absence of a tray of palatable foods that they did not eat. Results showed no effect of fed or fasted condition, presence or absence of food, or any interaction between exposure and feeding condition on PFS scores. The authors conclude that the presence of food and a 4 hour fast do not affect PFS scores, so short-term fasting is unlikely to invalidate assessments of hedonic hunger.

Whilst the findings of Witt et al. (2014) discussed above indicate that short fasting times prior to measurement are unlikely to be problematic for PFS scores, no information about longer fasts is available. Some participants in the WRAP trial attended study visits in a fast state as this was required prior to phlebotomy procedures that were part of the trial (Ahern et al., 2017a). The impact of this on PFS scores is addressed in Section 2.3.9.

1.4.4. Relationship with obesity

Evidence for a correlational relationship between hedonic hunger and obesity is somewhat mixed. In an initial validation study for the PFS, Cappelleri et al.(2009) showed a small, positive correlation between PFS total score and BMI, indicating that higher hedonic hunger was associated with higher BMI. Similarly, Thomas et al. (2013) reported that PFS scores were higher in participants classified as obese-prone, than in those classified as obese-resistant. Furthermore, Cushing et al. (2014) indicated that hedonic hunger fluctuated in line with BMI over 2 years in 16 adolescents who underwent bariatric surgery, although the small sample size of this study limits the inferences that can be made from these results.

Contradictory evidence comes from multiple studies that have examined the relationship between hedonic hunger and BMI within a range of participant samples. Appelhans et al. (2011) showed no relationship between hedonic hunger and BMI in women with overweight and obesity. Mitchell et al. (2016) showed no association between PFS scores and BMI in a sample of 148 adolescents. Witt et al. (2014) reported no significant correlation between PFS total scores and BMI in a sample of normal weight young women. Burger, Sanders and Gilbert (2016) reported a reanalysis of a previous study (Burger, Cornier, Ingebrigtsen, & Johnson, 2011) and showed no association between PFS scores and BMI in a sample of 100 adults with normal weight or overweight. Participants in this study completed ratings of food appeal and desire to eat following exposure to food images. Hedonic hunger was not assessed in relation to these measures.

The contradictory nature of these findings indicate that the relationship between hedonic hunger and BMI is unclear, which could be explained in several ways. Firstly, sample differences between these studies may account for differences in findings. It does appear that studies that report a correlation between BMI and hedonic hunger are based on samples of with overweight or obesity, or individuals likely to be obese-prone. Conversely, studies that do not report significant associations are more heterogeneous in their samples, so a potential relationship may be less easily detected in these groups. A second explanation may be that elevated hedonic hunger is not unique to elevated BMI's. Indeed, the ranges of PFS scores between studies may have be comparable, although they are not consistently reported to allow inspection of this. In this thesis I examined relationships between hedonic hunger and BMI in an attempt to provide further evidence on this matter.

1.4.5. Relationship with disordered eating

Several recent studies (Davis et al., 2009; Lowe et al., 2016a; Manasse et al., 2015; Witt & Lowe, 2014; discussed below) have explicitly assessed the role of hedonic hunger as measured by the PFS in disordered eating. It should also be noted that other studies have shown positive associations between more frequent/likely "hedonic" eating not measured by the PFS and disordered eating (e.g. Holsen et al., 2012; Monteleone et al., 2016), however as disordered eating is not the primary focus of this thesis, and the PFS is the primary assessment tool for hedonic hunger, discussion of this literature is brief and limited to studies that used the PFS to measure hedonic hunger.

In addition to being associated with several appetitive factors that are relevant to obesity hedonic hunger may be involved in disordered eating. The rationale for this suggestions follows a recent meta-analysis of studies exploring hunger and binge eating in individuals with binge eating disorder (BED) and bulimia nervosa (BN; Haedt-Matt & Keel, 2011). BED and BN are eating disorders characterised by intake of objectively or subjectively large quantities of food within a discrete period of time, typically accompanied by feelings of loss of control (BED and BN; Fairburn & Cooper, 1984), and that may be followed by purging behaviours (BN; American Psychiatric Association, 2013). Haedt-Matt and Keel (2011) comment that it had previously been thought that excessive hunger following dietary restriction was a key driver in the onset on binge eating, but findings of their meta-analysis showed that levels of hunger measured prior to binge episodes were lower than measures of hunger taken before non-binge eating episodes. This implies that homeostatic hunger alone, or hunger for energy needs, cannot explain binge eating and others (e.g. Witt and Lowe, 2014; discussed below) have suggested that hedonic hunger may also be at play prior to binge episodes because dietary restriction, common in BED and BN, may be inducing both homeostatic deprivation and hedonic deprivation.

Convincing evidence for a role for hedonic hunger in disordered eating has been shown in studies that compared PFS scores between clinical and non-clinical samples, and assessed the relationship between PFS scores and symptom severity. For example, Witt and Lowe (2014) examined the relationship between hedonic hunger, as measured by the PFS, with binge eating in female patients admitted to an

inpatient eating disorder treatment centre.   Results showed that hedonic hunger was higher in patients with BN than those with anorexia nervosa (AN; subtypes of AN collapsed) and non-clinical control samples. Greater PFS scores were also significantly associated with a higher frequency of objective and subjective binge eating episodes in patients with BN and AN. Interestingly, higher pre-treatment PFS scores also predicted greater weight gain in patients with AN (but not BN). This may be reflective of greater hedonic drive promoting increased food consumption for weight regain, which is a theme examined throughout this thesis albeit from a complimentary perspective of weight reduction.

Higher scores on the PFS have also been shown among treatment-seeking women with overweight or obesity who endorse binge eating (BE), than among women with overweight and obesity who did not meet criteria for BE (Manasse et al., 2015). Similar results have been shown by Davis et al. (2009) who report higher PFS scores for individuals with obesity meeting criteria for BED than adults without obesity and BED. Furthermore, Lowe et al. (2016) extended findings that associated hedonic hunger with disordered eating by examining how PFS scores predicted the maintenance and onset of loss of control (LOC) eating in college women. While LOC eating itself is not an eating disorder, it is a defining feature of BE in that BE is typically accompanied by the sensation that the individual has lost control of how much and/or what they are eating (American Psychiatric Association, 2013), thus making LOC eating a maladaptive eating behaviour. College women with greater hedonic hunger were more likely to develop LOC eating over a 2 year period than

those with lower hedonic hunger, and women with coexisting LOC eating and higher hedonic hunger showed limited reduction in LOC eating over 2 years.

Taken together, the studies reviewed in this section indicate that higher levels of hedonic hunger are found in individuals who display disordered eating than in individuals who do not meet criteria for eating disorders. Specifically, it appears that hedonic hunger may be an additional factor other than homeostatic hunger that drives disordered eating characteristics such as BE and LOC eating. It could be suggested that the increased drive for palatable foods for their rewarding properties that is characteristic of hedonic hunger may at some point (or when experienced in combination with other, unknown factors) become strong enough that it becomes maladaptive, making some individuals more susceptible to BE and LOC eating. Alternatively, the opposite may be true and individuals who display disordered eating that is likely driven by an increased sensitivity to the rewarding values of food may then score higher on measures of hedonic hunger, because the repeated exposure to palatable food during BE strengthens their sensitivity to the rewarding properties of food, which in turn manifests as higher hedonic hunger. Interestingly, the finding that patients with AN and greater hedonic hunger successfully regained more weight during treatment (Witt and Lowe, 2014) than those with lower hedonic hunger strengthens the suggestion that higher hedonic hunger makes some individuals more susceptible to overeating. In non-clinical cases this susceptibility would be maladaptive, but in these patients having a heightened response to the rewarding properties of food could have been beneficial in a

therapeutic setting. Exploration of this proposal is beyond the focus of this thesis but future work could address this.

1.4.6. Ghrelin and endocannabinoid abnormalities

Originally identified in the rat gut (Kojima et al., 1999), ghrelin, a gut peptide, mediates food intake by stimulating appetite (Kojima, Hosoda, & Kangawa, 2004). Research has since shown that ghrelin concentrations correlate with hunger sensations and decline upon satiation (Cummings, 2006). Ghrelin has also been shown to stimulate weight gain by increasing adiposity when administered to rodents, causing them to develop obesity (Tschöp, Smiley, & Heiman, 2000). Furthermore ghrelin has been implicated in food reward processing (Perello & Dickson, (2015).

The endocannabinoid system, particularly the lipid mediators 2-arachidonyl-glycerol (2-AG) and anandamide (AEA), has also been implicated in appetite regulation. It achieves this by activating brain receptors involved in feeding (Di Marzo, Ligresti, & Cristino, 2009). Research shows that ghrelin and 2-AG are involved in reward processes triggered by palatable food (Di Marzo et al., 2009; Jerlhag et al., 2007). Of most relevance to this thesis, a series of studies have shown that blood plasma concentrations of ghrelin and 2-AG rise in response to hedonic eating, relative to non-hedonic eating (Monteleone et al., 2016a; Monteleone et al., 2016b; Monteleone et al., 2015; Monteleone et al., 2012; Rigamonti et al., 2015). While these researchers did not explicitly measure hedonic hunger using the PFS, they propose that they used experimental paradigms that captured hedonic hunger,

or at least non-homeostatic eating. Four of the studies provided sated participants with *ad libitum* access to their self-reported favourite food that they would likely eat for pleasure (e.g. sponge cake with syrup, ice cream, chocolate and biscuit bars; Monteleone et al., 2016a; Monteleone et al., 2016b; Monteleone et al., 2015; Monteleone et al., 2012), whereas one study (Rigamonti et al., 2015) provided participants with chocolate (to represent a palatable food). All studies compared ghrelin and endocannabinoid blood concentrations after participants ingested the palatable food to blood concentrations taken after they had eaten a portion of a non-favourite food identified as something not typically consumed for pleasure (e.g. bread and butter). Portions of non-favourite foods were equicaloric to the *ad libitum* consumed portions of favourite foods.

Results of the studies discussed above showed a differential pattern for blood concentrations of ghrelin and endocannabinoids following hedonic versus non-hedonic eating. Greater ghrelin concentrations after hedonic versus non-hedonic eating were detected in subjects with obesity (Rigamonti et al., 2015) and subjects with a healthy weight (Monteleone et al., 2016b; Monteleone et al., 2012). Deranged endocannabinoid levels (2-AG and AEA) were also observed in accordance with hedonic versus non-hedonic eating in participants with obesity (Monteleone et al., 2016a; Rigamonti et al., 2015) and healthy weight subjects (Monteleone et al., 2015; Monteleone et al., 2012). Interestingly, two of these studies compared ghrelin and endocannabinoid responses to hedonic versus nonhedonic eating in healthy weight participants to participants with active AN (Monteleone et al., 2016b; Monteleone et al., 2015). Results from patients with AN did not show

clear differences in blood concentrations of ghrelin and endocannabinoids for hedonic versus non-hedonic eating, suggesting that the hedonic eating episodes were not associated with changes in physiological markers of reward processes triggered by palatable food. This fits with theories of abnormal reward processes in AN (Park, Godier, & Cowdrey, 2014). Taken together, the absence of physiological markers of reward in individuals with AN who also display reward processing deficits, and the heightened levels of such markers following hedonic eating in non-clinical participant samples suggests that hedonic motivation for food is associated with not only obesity (Section 1.5.3), but also physiological markers of reward processing.

1.4.7. Relationship with food intake

In addition to being associated with physiological markers of eating, some evidence is beginning to emerge that suggests hedonic hunger is associated with food intake in the laboratory and day-to-day environment. Within the laboratory, two related studies have indicated that an interaction between hedonic hunger and delay discounting may predict food intake. Delay discounting is a measure of inhibitory control and is assessed by comparing choices for smaller, immediate rewards to larger, later rewards (Rollins, Dearing, & Epstein, 2010). Appelhans et al. (2011) assessed hedonic hunger, delay discounting and laboratory snack food intake in women with overweight and obesity. Results showed that delay discounting and hedonic hunger interacted to predict snack food intake. Women with elevated hedonic hunger and delay discounting ate more than those with low delay discounting and low levels hedonic hunger. Similar results were shown by Ely,

Howard and Lowe (2015) in a sample of women with normal weight or overweight. Ely et al. (2015) showed that PFS scores and delay discounting interacted to predict food intake over a study day (self-served preload plus snack intake, but not snack intake alone). The same pattern of results as in Appelhans et al. emerged, with women with high hedonic hunger and high delay discounting consuming more food than women with high hedonic hunger and low delay discounting, and low hedonic hunger and high or low delay discounting. These results indicate that hedonic hunger represents a vulnerability to overconsuming food when inhibitory control is also limited.

Two recent studies have also indicated that higher hedonic hunger is associated with greater occurrence of everyday snacking behaviour. Stok et al. (2014) assessed hedonic hunger (PFS total score) and self-reported snacking and self-regulatory abilities in a large sample (n=11,392) of European adolescents. Findings showed that adolescents with higher hedonic hunger consumed more unhealthy snacks (e.g. candy bars per day), but greater self-regulatory abilities reduced this, implying that the ability to resist immediate temptation limited snacking.

Snack intake has also been associated with hedonic hunger in adults (Schüz, Schüz, & Ferguson, 2015). Schüz et al. (2015) assessed the average number of snacks eaten per day over a 10-day period, and hedonic hunger in adults. This study revealed that higher hedonic hunger (higher PFS scores) was associated with more daily snacking on average. This was also moderated by negative affect, in that participants with high hedonic hunger were also more likely to snack when

experiencing negative affect. Negative affect and has been suggested to make resisting eating temptations more difficult for some individuals with overweight and obesity (Jansen et al., 2008). This can be interpreted as an additional way that hedonic hunger is a barrier to weight management.

These findings indicate that hedonic hunger may contribute to overeating and represent a barrier to successful weight management. An implication if this is that interventions that aim to reduce hedonic hunger may also reduce food consumption, which may in turn be beneficial to weight regulation. As yet, no such interventions have been described. The current thesis made a first attempt to achieve this in Chapter 5.

1.4.8. Neural correlates

A growing number of studies have suggested that there is an association between hedonic hunger and neural correlates of eating regulation and cue reactivity. Some studies have also suggested that neural correlates of appetitive responses are different between participants with high and low hedonic hunger. One such study by Rejeski et al.(2012) performed neural network analyses using functional Magnetic Resonance Imaging (fMRI) data recorded from participants in a fasted and a short-term post-absorptive state. This analysis was performed on recordings of the default mode network, which represents the brain's resting state. In this study, older (50-80 years), participants with obesity consumed a fixed breakfast, fasted for 2.5 hours, then drank a nutritional supplement drink or the equivalent amount of water (counterbalanced over repeated sessions). The

supplement drink represented the removal of energy need. Participants completed a visualization task where they were presented with words that represented neutral items or their favourite foods and required them to engage as many senses as they could to produce a mental image of the item. Behavioural assessments were collected for craving for desired foods and participants' confidence in their ability to control their eating when exposed to their favourite food. Results showed that when participants with high hedonic hunger were exposed to food cues in the absence of energy need (supplement drink condition) they experienced greater craving for desired foods and reported less confidence in their ability to control their eating. Neural network analysis revealed that participants with high hedonic hunger did not return to their default mode network following cue exposure in the supplement drink condition. They instead showed greater connectivity between regions within and related to the prefrontal cortex (PFC) regions associated with behaviour regulation (medial PFC, occipital frontal cortex and insula). Participants with low hedonic hunger did not show this pattern of results. The authors interpret these results as suggesting that participants with higher hedonic hunger are predisposed to process internal cues related to food, and these cues dominate conscious thought, whereas participants with low hedonic hunger do not display this predisposition.

Further evidence of neural correlates of hedonic hunger comes from studies that examine frontal asymmetry in electroencephalography (EEG) brain activity. In a small study of 28 adults with overweight or obesity, Ochner et al. (2011) have demonstrated that PFS total scores, disinhibition and hunger predict left frontal

asymmetry in EEG recordings of the brain's resting state. The authors interpret this as left frontal asymmetry being associated with disinhibition and approach responses related to reward evaluation, whereas right asymmetry has been associated with restrained and avoidance responses in restrained eaters (Savage, Hoffman, & Birch, 2009). Similar findings have been found in a subsequent study by Winter et al. (2016), who showed greater left asymmetry in the PFC in participants with higher hedonic hunger, irrespective of if they scored high or low on a measure of dietary restraint. The PFC has been implicated in guiding and regulating responses to appetitive stimuli (Appelhans, 2009), and so left PFC asymmetry is interpreted as appetitive drives overwhelming inhibitory, avoidance responses. Taken together, these two studies suggest that heightened hedonic hunger is associated with neural correlates of approach responses. Complimentary results have also been reported by Jensen, Duraccio, Carbine, Barnett and Kirwan (2016), who reported negative correlations between PFC activity and PFS scores during presentation of high calorie food images. This reduced PFC activity is indicative of decreased inhibition to resist high calorie foods.

Evidence of a relationship between higher hedonic hunger and increased neural response to food stimuli has also been shown by Burger, Sanders, & Gilbert, (2016). In 3 studies, Burger et al. (2016) report increased levels of oral somatosensory brain responses to food images in participants with elevated hedonic hunger. They also show that individuals with higher hedonic hunger (assessed by PFS total score) reported that stimuli depicting energy dense foods were more appealing, were more likely to report current binge eating and showed

increased motivation to consume foods. These findings complement the above studies of resting neural state differences in participants with high and low hedonic hunger as they indicate that higher hedonic hunger is associated with displaying an elevated response to food stimuli across neural and behavioural modalities. Although, it should be noted that these studies do not provide evidence for how such differences in responsivity to food cues may be related to weight change. Burger et al. reported no associations between hedonic hunger and BMI over 2 years in their studies. However none of the studies described here have explored if food cue reactivity is associated with a relationship between hedonic hunger and reactivity to food cues. The current thesis attempts to address this gap in the literature in Chapter 4 by assessing relationships between hedonic hunger, BMI and food cue reactivity.

1.5. Hedonic hunger and weight management

The pleasure associated with eating and the difficulty this may present during weight loss has been acknowledged in the literature even before obesity rates began rising drastically in the late 20th century. For example, in an early report of the effectiveness of a low calorie diet administered for weight loss Rodger, McFetridge and Price (1950) noted that pleasure derived from eating may be problematic during dieting. More recently, the increased motivation for palatable foods which hedonic hunger reflects has been suggested as a barrier to weight loss success, such that individuals with elevated hedonic hunger may require alternative or additional support to overcome this during weight management (Lowe & Butryn,

2007). Evidence to suggest this has recently begun to emerge in the form of empirical studies that have examined hedonic hunger (as measured by the PFS) in individuals undergoing weight management. Emerging evidence comes from studies of nonsurgical and surgical weight management interventions. The role of hedonic hunger during weight management is a central theme of this thesis, so these studies will be described below.

1.5.1. Hedonic hunger in behavioural weight management

Two published studies have examined how hedonic changes hunger during behavioural weight management. Theim, Brown, Juarascio, Malcolm and O'Neil (2013) assessed changes in hedonic hunger, weight control behaviour usage and weight loss in 111 adults undergoing 15 weeks of behavioural weight management with partial meal replacement. Results showed that hedonic hunger decreased during weight loss, and greater hedonic hunger decreases were associated with greater weight loss. A surprising finding from this study was that participants with elevated baseline hedonic hunger showed the greater weight loss than those with low hedonic hunger. This finding seems to be in contrast to what would be expected from predictions of high hedonic hunger being a barrier to weight loss success. An explanation for this may be that the meal replacement element of the study limits the opportunities for exposure to highly palatable food, so participants with high hedonic hunger benefit from this as the limited exposure to palatable foods reduces the opportunities for overeating in response to palatable foods.

A further study that is of particular relevance to the current thesis has been described by O'Neil, Theim, Boeka, Johnson & Miller-Kovach (2012). Participants in this study were 111 adults who underwent 12 weeks of behavioural weight loss (Weight Watchers served as the intervention). As in Theim et al. (2013), PFS scores and weight control behaviour usage were measured. Results showed that participants lost weight during the course of the study, and that PFS scores reduced. Furthermore, results showed that reductions in hedonic hunger and increases in weight control behaviour usage were associated with greater weight loss, particularly in participants who were assessed as having high baseline hedonic hunger. These results suggest that reducing hedonic hunger may aid weight loss, although it is difficult to conclude that the effects reported in this study are a result of the intervention or other factors because no control group was assessed.

1.5.2. Hedonic hunger and surgical weight management

Evidence for altered hedonic hunger in association with surgical weight loss has recently begun to emerge. Schultes, Ernst, Wilms, Thurnheer and Hallschmid (2010) have reported that hedonic hunger (PFS scores) is lower in patients who have undergone bariatric surgery than in individuals with severe obesity who are awaiting surgery, and control participants without obesity. Similar findings are reported by Ullrich et al. (2013), who reported lower PFS scores in patients who had undergone gastric banding surgery than those who were awaiting surgery. PFS scores from post-surgery patients were also comparable to those of control participants without obesity. Ullrich et al. (2013) have suggested that these results suggest that bariatric

surgery "normalises" hedonic hunger, although this interpretation should be treated with caution because of the lack of within-subject data that supports this.

Two small studies have reported changes in hedonic hunger scores assessed in the same patients pre-post-surgery. In a limited sample of 16 adolescents, hedonic hunger and BMI appeared to follow the same non-linear trend: both decreased in parallel in the first 18 months following surgery and slight increases were seen in both hedonic hunger and BMI 24 months post-surgery (Cushing et al., 2014). In a sample of 47 adults, PFS scores were reduced following surgery although correlation with BMI change was not reported (Ullrich, Ernst, Wilms, Thurnheer, & Schultes, 2013). These findings mirror those of previous studies and support the notion that hedonic hunger is reduced following bariatric surgery; however the reasons for this are still unknown. Hedonic hunger could be reduced due to conditioning effects, whereby inability to comfortably consume previously desired foods dampens their appeal (their reward value is reduced). Furthermore, it is not known how patients with high pre-operative levels of hedonic hunger may manage this post-operatively, compared to those with low pre-operative levels of hedonic hunger

1.5.3. Hedonic hunger and BMI in weight-related, but not weight-loss, interventions

In addition to a growing number of studies that report hedonic hunger measurements during weight loss, two studies have reported assessment of PFS score and BMI in weight-related studies that did not target weight loss.

Burger, Sanders and Gilbert (2016) report an exploration of the relationship between hedonic hunger and BMI in a reanalysis of data from two previously published studies. Study 1 was a reanalysis of data from adolescent girls with body dissatisfaction who took part in an eating disorder prevention programme, control intervention or wait-list control (Stice, Shaw, Burton, & Wade, 2006). Study 2 (Stice, Yokum, Blum, & Bohon, 2010) assessed neural activity to food cues in women with overweight who had gained weight over a 6 month period. Analysis of data from both studies showed no relationship between baseline PFS scores and BMI, or between baseline PFS score and changes in BMI. These results should be interpreted with caution because the rationale for including assessments of hedonic hunger in the described interventions is unclear.

A second study of note that examined hedonic hunger and BMI outside of a weight loss intervention is from McCoy et al. (2017). These authors assessed PFS score and weight in 17 men undergoing liver transplant surgery. Measurements were taken pre-surgery and 6-months post-surgery. This study showed that weight increased pre-post surgery, as did PFS total score, which the authors interpret as indicating an increased appetitive drive (hedonic hunger) during the 6 months following surgery. No analysis of the relationship between change in PFS score and change in weight is reported.

1.5.4. Issues with this research

While the research discussed in sections 1.5.1 and 1.5.2 shows that hedonic hunger, as measured by the PFS, may change during weight loss, the studies that

support this notion are often limited. There is a limited amount of evidence in support of hedonic hunger changing during weight management that has actually tracked hedonic hunger in the same participant groups as they progress through a weight loss intervention. In fact, some of the support for this proposition is drawn from studies that have compared PFS scores in patients that have undergone weight loss to scores in a separate group of patients that are awaiting weight loss. For example, Schultes, Ernst, Wilms, Thurnheerand Hallschmid (2010) compared such patient groups and a control group of participants without obesity, as did (Ullrich et al., 2013).

The cross-sectional nature of previous findings makes it difficult to confidently assert that hedonic hunger changes with weight loss, although other authors have tracked hedonic hunger and weight within the same group of patients over time, albeit in smaller patient samples (Cushing et al., 2014; Ullrich et al., 2013). Other studies that examined changes in hedonic hunger during non-surgical weight loss (O'Neil et al., 2012; Theim, Brown, Juarascio, Malcolm, & O'Neil, 2013) used repeated measures design and compared pre-intervention to post-intervention scores within participants. However, the mixture of study designs within the literature surrounding the relationship between hedonic hunger and weight loss highlights that more work that tracks PFS scores in large groups of participants over time is needed in order to more clearly understand what role, if any at all, hedonic hunger plays in weight loss. Extending the evidence surrounding this is one of the aims of this thesis and Chapters 3 and 4 assess hedonic hunger during weight loss within participant groups.

An additional limitation to the proposal that hedonic hunger changes during weight loss is the lack of exploration of the possible interventions driving this change. The studies discussed above (Sections 1.5.1 and 1.5.2) do not explore the reasons *why* or *how* hedonic hunger changes during weight loss, or how hedonic hunger may affect weight loss (or weight gain, as in McCoy et al., (2017)). Evidence for the mechanisms that dirve this change is lacking, therefore the current thesis aimed to explore food cue reactivity as a potential mechanism that may explain or underlie these changes. Kremers, Reubsaet, Martens, Gerards, Jonkers, Candel et al. (2010), in a review of 46 weight management studies, highlighted that while studies report the effectiveness of interventions, few, if any speculate on or assess the mechanisms that underlie the behavioural changes observed .By exploring the role of hedonic hunger in predicting weight loss during a weight management trial this thesis aimed to address this criticism of weight management interventions.

1.6. Food cue reactivity

Over the past decade our understanding of what hedonic hunger is and associated eating-related factors has been extended by studies that investigated behavioural correlates of hedonic hunger, and studies that examined hedonic hunger during weight loss. There are, however, still a number of unanswered questions about how hedonic hunger may manifest in the laboratory or natural environment, or how hedonic hunger may predict or pose a barrier to weight loss success.

One such potential manifestation of hedonic hunger may be through enhanced food cue reactivity. Cue reactivity is a conditioned physiological and/or psychological response to cues (Boswell & Kober, 2016). Lowe and Butryn (2007) originally posited that hedonic hunger may be triggered by environmental food cues, and some authors have described the PFS as analogous to a measure of reactivity to the food environment (e.g. Stok et al., 2014). In obesogenic environments cues that signify the presence and availability of palatable food are abundant, and such foods are heavily and aggressively marketed (Boyland, Harrold, Kirkham, & Halford, 2011), which may prompt overeating and undermine weight loss attempts. Evidence has shown that individuals with elevated levels of hedonic hunger may respond differently to food cues than those with lower levels of hedonic hunger (Burger et al., 2016; Ochner et al., 2011), so food cue reactivity may represent a behavioural manifestation of hedonic hunger. In light of this, the current thesis examined relationships between hedonic hunger and food cue reactivity during weight management. To support this rationale, an overview of food cue reactivity is presented below.

1.6.1. Background information relating to food cue reactivity

Evidence for the effects of food cues on eating behaviour was initially reported in the mid-20th century. Hashim and Van Italllie (1965) and Nisbett (1968) reported that individuals with obesity consumed more or less of a food depending on its palatability than did lean individuals, indicating that the external factor of palatability was influencing food intake, not internal homeostatic signals. These findings inspired Schachter's externality theory of obesity (Schachter & Gross, 1968),

which recognised that individuals with obesity have a propensity to eat more in response to external influences (e.g. food cues). Since this time, research has shown that individuals with overweight or obesity consume more when exposed to a food cue (Nijs, Muris, Euser, & Franken, 2010).

1.6.2. Development of food cue reactivity

An explanation for how food cue reactivity develops comes from Incentive Salience Theory (IST; Robinson & Berridge, 1993; Robinson & Berridge, 2003). Originally developed to explain dependence on addictive substances, IST can be applied to explanations of food cue reactivity (Berridge, 2009; Field et al., 2016). IST proposes that the consumption of a desired substance, such as palatable food, produces a dopamine response in reward-related areas of the brain. Repeated consumption sensitises this response, increasing the motivational appeal of the substance (Volkow et al., 2006). Through associative learning the cue becomes associated with the response and the cue acquires motivational properties. With repeated pairings over time the cue itself becomes attractive and wanted and, as a consequence, attracts, grabs and maintains attention (Robinson & Berridge, 1993). In line with suggestions that there are individual differences in responses to the obesogenic environment, individual differences in the way food cues hold attention have also been observed (Tapper, Pothos, & Lawrence, 2010).

1.6.3. Food cue reactivity and obesity

Evidence for a relationship between food cue reactivity and obesity comes from studies that have examined the relationship between responses to food cues

and eating behaviour. This has been supported by a recent meta-analysis which showed that food cue reactivity and craving predict food-related outcomes (intake) (Boswell & Kober, 2016), and by laboratory studies that show associations between measures of food cue reactivity and eating-related behaviours. For example, Lawrence et al. (2012) observed heightened neural responses in the nucleus accumbens (NAcc) in response to visual food stimuli. The NAcc has previously been implicated in food motivation and reward, and Lawrence et al. (2012) reported that NAcc activity in their study was positively associated with greater food consumption in a subsequent taste test.

The potential impact of food cue reactivity on obesity can be seen in work that has examined its relationship with weight management. Murdaugh, Cox, Cook Iii and Weller (2012) assessed food cue reactivity by measuring neural activation in reward-related areas (NAcc, anterior cingulate and insula) whilst participants with obesity viewed images of high calorie food and neutral stimuli. Assessments were taken before and after a 12-week psycho-social weight management intervention, and at a 9-month follow up. Results showed that greater activation in reward-related brain regions prior to starting the weight loss activation predicted poorer weight loss outcomes at 9 month follow up. These results can be interpreted as suggesting that a greater reward-related response to high calorie foods represent an increased attentional attenuation to such foods, which may prove challenging when attempting to lose weight.

In addition to neuroimaging data, self-reported assessment of food cue reactivity has been shown to predict overeating. Tetley, Brunstrom and Griffiths

(2009) assessed ratings of desire to eat, craving and desired portion size before and after participants were exposed to the sight and smell of pizza. Importantly, participants did not eat this pizza, so this procedure represents food cue exposure. No differences in desire to eat or craving were seen between participants with normal weight or overweight; however results showed that participants with overweight experienced a greater change in desired portion size of the cued food. The increase in portion size reflected 47kcals, which is relatively small but, if consistently consumed in excess of usual intake over time could contribute to excess weight. These results therefore complement findings from neuroimaging work which suggests that food cue reactivity is related to obesity and may represent a challenge to successful weight management.

1.6.3.1. Measurement of food cue reactivity

There a multiple means of measuring food cue reactivity detailed within the literature. Discussion of each method is beyond the scope of this thesis so methods are mentioned briefly.

Measurement of food cue reactivity is based on the cue reactivity paradigm. This paradigm involves exposure to a cue, via image, physical presence, or smell, and measurement of its effect on physiological and/or psychological reactions (Carter & Tiffany, 1999; Drummond, 2000). The effect of the cue on physiological and psychological reaction can be measured as altered neural responses to cues (Murdaugh et al., 2012; Nijs et al., 2010), desire to eat ratings (Tetley et al., 2009), salivary response (Ferriday & Brunstrom, 2011) and attentional capture (Tapper et

al., 2010). In this thesis I focussed on attentional effects of food cue reactivity, specifically attentional bias.

1.6.3.2. Attentional bias

According to IST (Berridge & Robinson, 2003; Robinson & Berridge, 1993), food cues obtain motivational value as a result of repeated cue-stimulus pairings. Over time the cue becomes more salient and attention is sensitised to it, leading to an increased tendency for attention to be captured by the cue (Werthmann, Jansen, & Roefs, 2014). This increased tendency is referred to as attentional bias (AB) and may arise in obesity due to the tendency for overevaluation of food in individuals with obesity (Volkow, Wang, Fowler & Telang, 2008).

Recent reviews have indicated that AB to food cues is associated with obesity and food consumption (Field et al., 2016; Hendrikse et al., 2015). Indeed, differences in AB in participants with or without obesity have been shown in a number of studies. For example Castellanos et al. (2009) assessed AB in participants with or without obesity under conditions of hunger and satiety. Results showed that while participants with and without obesity showed AB to food cues whilst hungry, only participants with obesity maintained AB after feeding, whereas lean participants did not. Castellanos et al. interpret this finding as reflective of obese-lean differences in reward processing (see also Volkow, Wang, Fowler & Telang, 2008). This has also been reflected in neuroimaging work. Yokum, Ng and Stice (2011) assessed AB by measuring manual response times and neural responses to appetising and unappetising food in adolescent girls. Higher BMI was shown to be associated with

greater AB to food cues, in that participants with higher BMI responded more quickly to food images.

In addition to being associated with obesity, AB also appears to be related to food intake. Nijs et al. (2010) has demonstrated that AB is related to food intake in participants with obesity. Similar results have been shown in participants with normal weight by Werthmann, Renner, et al. (2014). Werthmann, Renner, et al. (2014) assessed AB to high calorie foods and a*d libitum* snack food intake in female participants assigned to either a sad or neutral mood induction condition. No effect of the mood induction was seen on AB or food intake, but greater AB was associated with increased food intake in the neutral condition.

Taken together, the results of these studies and reviews highlight an association between AB and obesity-related eating behaviours. Findings such as these suggest that a heightened attentional bias for food cues may represent a potential risk factor for excess weight. This heightened sensitivity to the rewarding values of abundant and typically unhealthy palatable foods is likely to make resisting them even more difficult when individuals engage in weight management.

1.6.3.2.1. Measuring attentional bias

The visual probe task (MacLeod, Mathews, & Tata, 1986) is a computerised method for assessing AB that is widely used in assessments of food AB (e.g. Field et al., 2016; Lattimore & Mead, 2015; Nijs et al., 2010; Werthmann et al., 2011). In this task participants are presented with a display of two stimuli, one "critical" and one neutral. Critical stimuli typically represent the topic that AB is being assessed for. For

example, assessments of AB to food stimuli that use a visual probe task may present food images (or words) alongside neutral images (or words). Neutral images are non-target items, such as office supplies and household items.

Stimuli in the visual probe task are presented adjacent to each other on a computer screen. This display is swiftly followed by a visual probe, commonly a dot or an arrow, that appears in the location of one of the two previously seen stimuli. Participants must indicate the location or identity of the probe by pressing a predetermined response key. The rationale behind this task assumes that responses are faster to probes that appear in the previously attended location, so if attention was previously directed to the critical stimulus and the probe appears in this location, the participant will be quicker to respond than if they were not attending to that location, thus indicating attentional bias. Concurrent eye-movement recording also provides a more direct view of the time course of attention during an experimental trial and has been suggested to improve the internal validity of the visual probe task to a greater extent than reaction time (indirect) indexes of AB (Christiansen, Mansfield, Duckworth, Field, & Jones, 2015). Combining eye-movement recording and reaction time monitoring allows for direct and indirect indexes of attentional bias to be calculated.

An alternative task used for measuring AB is the Stroop task (Stroop, 1935). In the Stroop task words are presented in colour and the participant's task is to name the colour the word is presented in (the colour of the ink) and ignore the meaning of the word. Latency of colour naming for words in a target category (e.g. food) can be compared to colour-naming latencies for non-target category words

(e.g. household items). If participants are slower to name colours of target words than non-target words, the inference is that target words captured attention. This interference with colour naming reflects AB. AB to unhealthy food words as assessed by the Stroop task has been shown to predict increased future BMI in undergraduate university students (Pothos, Calitri, Tapper, Brunstrom, & Rogers, 2009). In children, AB to food words has been shown to be greater in children with obesity than children with normal weight (Braet & Crombez, 2003).

Despite findings of a relationship between AB and weight status using the Stroop task, the visual probe task has been proposed to be a superior method for assessing AB, particularly when combined with concurrent eye movement recording (Field et al., 2016). This is because slower colour naming times in the Stroop task cannot be used to determine if attention is being captured or directed away from a category of stimuli. The visual probe task, however, can be used to distinguish between approach and avoidance processes. In the visual probe task approach toward and attentional avoidance can be assessed indirectly by calculating bias scores based on the difference between response times to probes that replace critical versus neutral stimuli (Hardman, Jones, Field, & Werthmann, 2017). The addition of eye movement recording can extend this further as this allows for total fixation times to stimuli to be recorded. A direct index of AB can be calculated from this by calculating the difference between length of fixation on stimuli in different categories (Christiansen, Mansfield, Duckworth, Field, & Jones, 2015). In light of these considerations, the current thesis used a visual probe task with concurrent eye movement recording to measure AB.

1.6.3.2.2. Attentional bias retraining

Previous attempts to manipulate attentional bias have used an attentional bias retraining programme similar to that of Field and Eastwood (2005). These retraining programmes use a commonly employed indirect measure of attentional bias, the visual probe task (MacLeod et al., 1986) or similar, and adapt it to retrain attention towards or away from a particular class of stimuli.

Visual probe tasks that are designed to assess attentional bias are typically structured so that the probe replaces critical and neutral stimuli with equal likelihood. In attentional bias retraining programmes this contingency is manipulated (Field & Eastwood, 2005). For example, in a programme designed to train attention away from alcohol cues, the task may be programmed to only replace neutral images with the probe, never alcohol images, thus driving attention away from the alcohol stimuli (Field & Eastwood, 2005). For food-based visual probe tasks the probe may never or may very infrequently replace a food image if attention is being trained away from a food (e.g. Kemps, Tiggemann, Orr, & Grear, 2014). Alternatively, if attention is to be trained towards cues, e.g. towards healthy foods (Kakoschke, Kemps, & Tiggemann, 2014), the probe may replace only or mostly food images rather than neutral images. This modified version of the visual probe task constitutes a "training phase". This is preceded and followed by the traditional attentional bias task whereby the probe replaces critical and neutral stimuli with equal frequency. By completing the traditional version of the task before and after the training phase, change in attentional bias can be observed.

Attentional bias retraining programmes have been used to reduce AB and/or target behaviours in clinical research studies (e.g. Amir, Beard, Burns, & Bomyea, 2009) and non-clinical research areas (Attwood, O'Sullivan, Leonards, Mackintosh & Munafò, 2008) with mixed success (Field et al., 2009; Hardman et al., 2013; Werthmann et al., 2015). For example, Hardman et al. (2013) saw no effects of retraining on AB reduction and subsequent cake consumption, noting that AB appears to be particularly resistant to modification.

The findings reported by Hardman et al. (2013) are in contrast to results described by Kemps, Tiggemann and Hollitt (2014). Kemps et al. (2014) tested the effects of attentional bias retraining by training participants to either attend to or avoid food images (relative to non-food images). Their protocol consisted of a single retraining session and this was sufficient to induce the expected changes to attentional bias: pre- to post-training, the avoid food group showed decreased attentional bias and the attend food group showed an increase in attentional bias towards food cues. These effects generalised to another task that measured bias in attentional processing, suggesting that the effects of the ABR intervention worked on an underlying attentional mechanism rather than performance on the visual probe task. Whilst these findings are promising support for the effectiveness of ABR, Kemps et al. did not explore the effects of these changes on food intake. More evidence for the effect of ABR on food intake, if any, is needed to support the use of ABR in changing target behaviours (e.g. food intake) both in and beyond the laboratory.

1.6.3.2.3. Effects of attentional bias retraining on food intake

In two experiments utilising the adapted visual probe task described above, Kemps, Tiggemann, Orr and Grear (2014) demonstrated that a single attentional bias retraining session was sufficient to modify attentional bias to chocolate cues in 198 undergraduate women, aged 17 to 26 years. In both experiments, participants who were trained to attend chocolate cues showed increased attentional bias to such cues following training, and participants trained to avoid chocolate cues showed decreased attentional bias to chocolate cues following training. These reductions generalised to a novel set of chocolate stimuli in experiment two: the participants trained to avoid chocolate cues showed a smaller attentional bias for novel chocolate stimuli at post-test than participants trained to attend chocolate cues. Furthermore, these group differences were reflected in chocolate consumption during a bogus taste test. In both experiments, participants trained to avoid chocolate cues ate significantly fewer grams of chocolate muffin than those trained to attend chocolate cues (17.3g less in experiment 1; 21.63g less in experiment 2; the authors report these differences as statistically significant at $p<.05$), thus highlighting the potential for ABR as a possible means of reducing chocolate consumption.

Findings from Kemps, Tiggemann and Orr, et al. (2014) suggest that a single session of computer-based ABR was adequate to produce an immediate reduction in attentional bias. The finding that the effects of this training were not limited to the specific stimuli used in the training is particularly promising support for the

effectiveness of ABR. The authors note that for ABR to have real-world applications the training effects must generalise beyond experimental stimuli. Unhealthy food cues are abundant in the Western food environment and will not be limited to the types of cues used in attentional bias retraining programmes. The attentional changes produced by what is a relatively simple attentional retraining programme may well be sufficient to equip participants with the abilities to avoid reacting to related, tempting cues in everyday life, however more extensive work that replicates these findings is needed before this proposition can be fully explored.

1.6.3.2.4. Alternative methods of retraining attentional bias

Other methods of manipulating attention allocation to food cues have been described by Boutelle, Kuckertz, Carlson and Amir (2014), and Werthmann et al. (2014). Werthmann et al. employed an adapted anti-saccade task as a direct method of modifying attentional processing and required participants to attend images of either shoes or chocolate. Results showed that participants with more accurate responses to the task (as assessed through eye movement recordings) consumed more chocolate when attending to chocolate cues and ate less chocolate when attending to shoe images. This suggests that in order for attentional training to be effective, correct task understanding and performance is critical. Moreover, although Werthmann et al. finding of greater chocolate consumption when participants were attending to chocolate cues may appear at odds with the proposal for using attentional bias retraining to decrease reactivity to and consumption of unhealthy foods, it supports the use of such paradigms. If attentional bias can be manipulated

to increase unhealthy food consumption, it stands to reason that the same attentional mechanism being manipulated to increase consumption can also be manipulated to decrease chocolate consumption. This mechanism appears to have been exploited by Kemps, Tiggemann and Orr et al. (2014), discussed above, to reduce chocolate muffin consumption.

Another alternative ABR method was used by Boutelle et al. (2014). Boutelle et al. used an attentional bias retraining procedure to modify attentional bias and reduce subsequent food intake in children aged 8-12 years old who were prone to eating in the absence of hunger (the intake of food after eating to satiety; (Fisher & Birch, 1999; Hill et al., 2008). This study used a word-based visual probe task to manipulate attentional bias to food-related words and subsequent snack food intake during a taste test. Children who were trained to direct their attention away from food-related words showed modest decreases in attentional bias and food consumption following attentional bias modification. Children in the control condition of this study, who were trained towards food and non-food related words with equal frequency, increased their snack food consumption. These results imply that the principle behind the attentional bias retraining paradigm used in this and the previously described studies may be an effective and simple tool for the successful modification of food-related AB and related snack food consumption. These studies also provide further support for the proposed link between attention allocation processes and eating behaviour, as manipulation of attentional bias had a subsequent effect on food intake. Furthermore, although the precise details of the paradigms employed in previous studies vary, the underlying principle of directing

attention away from or towards a specified class of stimuli through deliberate, repeated stimulus-probe pairings is evidently a powerful means of adapting attention allocation and target behaviours, at least within the laboratory setting.

1.6.3.2.5. Attentional bias and attentional bias retraining in relation to this thesis

By repeatedly directing participants' attention away from food cues and towards neutral cues the conditioned response to automatically orient attention to the food cue because of its higher rewarding value may be weakened. Following the logic of Robinson and Berridge (1993), evidence of AB for food cues may be interpreted as a possibly stronger conditioned relationship between food cues and rewarding foods. This is also in line with a model of food cue reactivity described by Jansen (1998), which proposed that avoiding palatable food is more challenging when food cue reactivity is heightened, which may also be applicable to those with heightened hedonic hunger. Thus it is reasonable to assume that an attentional bias retraining procedure that aims to direct attention away from highly palatable food cues would be effective in those with an already existing elevated level of hedonic hunger – individuals such as these would have the greatest potential for change. Chapter 4 of this thesis provides evidence for an association between changes in hedonic hunger and AB during weight loss, and Chapter 5 describes an unsuccessful attempt to use ABR to modify AB, hedonic hunger and food intake in individuals with high hedonic hunger.

1.7. Aims of this thesis

The literature reviewed in this chapter highlights that the role of hedonic hunger in weight loss is poorly understood. Little is also known about the relationship between hedonic hunger and obesity, and if food cue reactivity may represent an underlying mechanism of hedonic hunger. The literature reviewed here suggests that hedonic hunger decreases during weight loss, and that heightened reactivity to external cues is associated with obesity and eating behaviour. Evidence also suggests that elevated hedonic hunger may be a barrier to weight loss success, but the magnitude and nature of this proposed effect is not known. Furthermore, there is a lack of evidence that has identified potential candidate mechanisms that underpin the proposed relationships between hedonic hunger, obesity and weight loss.

This thesis sought to addresses these limitations through a series of studies that explored relationships between hedonic hunger, food cue reactivity, obesity and weight loss in adults. Therefore, the aims of this thesis were:

i) to examine the relationship between hedonic hunger and obesity

ii) to examine the role that hedonic hunger may play in weight loss

iii) to investigate if food cue reactivity was an underlying mechanism of hedonic hunger.

Chapter 2 describes the methods and measures used to address these aims. The combination of laboratory and self-report measures of assessment contributes to the strength of this work.

Chapter 3 details a large-scale longitudinal investigation of hedonic hunger and BMI in adults undergoing behavioural weight management. This work was conducted as part of a larger randomised clinical trial that investigated clinical and cost-effectiveness of weight management interventions. This work represents one of the largest assessments of hedonic hunger and BMI to date.

Chapter 4 examined the relationships between hedonic hunger and food cue reactivity, measured as AB, in adults undergoing behavioural weight management. Findings from this chapter were used to develop a potential intervention for reducing AB, hedonic hunger and food intake in individuals with elevated hedonic hunger. Chapter 5 assessed the feasibility and effectiveness of this intervention in adults identified as having elevated hedonic hunger.

Chapter 6 synthesises the original research findings from chapters 3-5 and evaluates them within the context of the wider understanding of theories of obesity. Recommendations for future work and the implications of the findings of this thesis are described, and the aims of the thesis are reviewed.

Chapter 2 - Methodology

This thesis will contribute to the literature surrounding hedonic hunger and food cue reactivity during weight management. This chapter describes the methods and measures used for data collection in Chapters 3-5 in detail. Research presented in Chapter 3 was conducted as part of a randomised control trial called Weight Loss Referrals for Adults in Primary Care, referred to henceforth as the WRAP trial.

2.1. Participants

Participants in this research were adults aged 18-83 years old (*Mean*= 53.21 years, *s.d.* =13.66). The studies presented in Chapters 3 and 4 were open to males and females; the study reported in Chapter 5 was open to females only. Only females were included in Chapter 5 because the majority of participants recruited to the study detailed in Chapter 4 were female, and the rationale for the study in Chapter 5 was based on findings from Chapter 4. Therefore, for consistency, only female participants were recruited in Chapter 5. Participants in Chapters 3 and 4 were overweight and obese adults. Participants in Chapter 5 were normal weight, overweight and obese adult women.

Participant recruitment strategies in each chapter differed considerably and so are presented separately for ease of reading. Recruitment strategy for Chapter 3 is presented in section 2.3.4; strategy for Chapter 4 is detailed in 2.7, and the strategy for Chapter 5 is described in 2.8.

2.2. Weight Watchers

Chapter 3 and 4 report studies that used Weight Watchers as an open group behavioural weight management intervention. Weight Watchers is a commercially available weight management intervention that also operates an NHS referral scheme, allowing primary care providers to offer patients a 12-week referral to Weight Watchers as a weight loss intervention (Weight Watchers, n.d.). The cost of this referral is met by the NHS so the patient is able to attend Weight Watchers free of charge. The Weight Watchers programme consists of dietary and physical exercise advice and behavioural support. Weight Watchers members are encouraged to attend weekly "meetings" for weighing and educational information delivered by trained lay people. There are approximately 6,000 Weight Watchers weekly meetings held in the UK (Weight Watchers, 2017).

At the time the WRAP trial was conducted the Weight Watchers programme utilised a dietary plan called Weight Watchers ProPoints®. This plan was based on "points", where food and activity were assigned a points value. Participants were allocated a daily points allowance with an additional set of points to be used flexibly throughout the week. Personal points allocation was based on gender, age, height, weight and physical activity level. Foods were assigned points based on total fat, carbohydrate, dietary fibre and protein, with healthier food options being assigned lower or zero points. Participants "spend" their points allowance on foods and adhering to the personal points allowance was proposed to facilitate weight loss

(Beeken, n.d.). Physical activity was also assigned points values and participants were able to "earn back" points by engaging in physical activity.

2.3. The WRAP trial

The WRAP trial was a multi-centre randomised controlled trial comparing the clinical and cost-effectiveness of primary care referral to a commercial weight loss provider for 12 weeks, referral for 52 weeks, and a brief self-help intervention. The commercial weight loss provider was Weight Watchers. The intervention arms of the WRAP trial are described throughout this thesis as follows:

- WW52 – referral to Weight Watchers for 52 weeks

- WW12 – referral to Weight Watchers for 12 weeks

- BI – Brief self-help intervention

Three study sites were involved in the WRAP trial: Medical Research Council – Human Nutrition Research Centre (Cambridge, UK), The University of Oxford (Oxford, UK) and the University of Liverpool (Liverpool, UK; study sites are henceforth referred to as "Cambridge", "Oxford" and "Liverpool"). The study protocol for the WRAP trial has been described by Ahern et al. (2014).

2.3.1. Overview of interventions

Commercial provider intervention: Participants randomised to one of the two commercial provider arms of the trial joined community Weight Watchers groups. Participants were provided with access to Weight Watchers free of charge for the duration of their assigned intervention. These participants were asked to avoid

telling members of their chosen Weight Watchers group or the group leader that they were participating in a research trial. The aim of this was to ensure that participants' experience of the intervention was not overly influenced by involvement in the research trial and approximated the experience of attending Weight Watchers in the community through a GP referral scheme.

The two commercial provider arms of the trial provided participants with access to Weight Watchers for either twelve (WW12) or fifty-two weeks (WW52). Participants were provided with a Referral Pack, free of charge, containing a list of Weight Watchers meetings local to their GP surgery, a Weight Watchers Registration Form, and vouchers to attend a weekly Weight Watchers meeting of their choice. Vouchers enabled participants to attend Weight Watchers meetings free of charge and were provided to the meeting leader in lieu of the weekly attendance fee. The voucher booklet and registration form were the same as used in GP referrals to Weight Watchers (Figure 2.1). Participants were also provided with an access code for the Weight Watchers "e-Source", which is an online resource for Weight Watchers members that provides tools for tracking ProPoints allowances, recipe creation and information about the Weight Watchers plan. The Referral Pack was explained to the participant by a member of research staff as part of the baseline visit.

Figure 2.1 Weight Watchers Referral Pack

Brief Self-Help Intervention: Participants randomised to the Brief Self-Help Intervention (BI) were provided with a booklet produced by the British Heart Foundation (British Heart Foundation, 2005) that contained advice about portion sizes, eating a balanced diet and self-directed weight loss. A member of the research team gave the participant a scripted overview (Appendix 2) of the contents of the booklet.

2.3.2. Randomisation

Participants were allocated to an intervention arm by a stratified randomisation sequence developed by the trial statistician (Ahern et al., 2014). Stratification was by study centre and gender with a block size of twelve and an allocation ration of 2:5:5 (BI:WW12:WW52). Randomisation occurred during the baseline (0 month) visit.

2.3.3. Study Visits

Participants in the WRAP trial attended four study visits at their local research centre (Liverpool and Cambridge) or GP practice (Oxford). Visits occurred at baseline (0 months), and at 3, 12 and 24 months. All participants were provided with two Participant Information Sheets (Appendix 3A and 3B) prior to attending the baseline visit. Participants provided informed consent and were randomised to an intervention at the baseline visit. The trial Consent Form is shown in Appendix 4.

Study visits also included anthropometric measures, measurement of blood pressure, fasted blood samples (baseline and 12 month visits only, if the participant was willing) and completion of psychological questionnaires. Body weight and body

fat (mass in kg and percentage) were measured at each visit using a Tanita four-point segmental body composition analyser. Height was measured using a wall-mounted stadiometer or equivalent at the baseline visit. Participants completed a questionnaire pack that included the Power of Food Scale (PFS; Appendix 5) and other questionnaires that assessed psychological well-being, health and eating behaviours within the study visit at baseline. Questionnaires for subsequent visits were sent to participants prior to their study visit for completion at home for collection at the study visit. This thesis considers height, weight (kg) and Power of Food Scale data from each study visit.

2.3.4. Participant Recruitment

Participants in the WRAP trial were recruited from twenty-three GP surgeries in England. Participants registered at GP surgeries located in the south of England were recruited by the Oxford and Cambridge study sites; participants in the North West of England were recruited by the Liverpool site. GP surgeries that did not already offer referral to commercial weight management services were identified using the Primary Care Research Network (PCRN). Individual GP practices that joined the study searched their patient database for potential participants. Patients were identified as potential participants if they were aged ≥18 years and had either a BMI ≥28 kg/m^2 or no recent BMI recorded in their medical records. GP practices excluded participants who were terminally ill, had a history of eating disorders or whom GP's felt it inappropriate to invite to attend the trial. Potential participants were contacted by letter sent from their GP practice informing them of the WRAP

trial. Between 23 GP practices, 13949 potential participants were contacted about the WRAP trial.

The letter sent to potential participants (Appendix 6, template for the invitation letter used by a GP practices recruited at the Liverpool site) gave an overview of the WRAP trial and the weight management programmes available through the trial. Potential participants were invited to contact their local study-coordinator for more information about the trial and a telephone screening.

Telephone screening

The telephone screening assessed potential participants' eligibility for the trial. The trial was explained in more detail to participants using a script (Appendix 7) and the eligibility criteria for the trial were verbally assessed. Potential participants who were deemed eligible to take part in the trial were sent the Participant Information Sheets (Appendix 3a and 3b) and a baseline appointment was scheduled. Recruitment and screening took place between October 2012 and February 2014.

During the telephone screening BMI was assessed using self-reported height and weight. In the event that the potential participant's BMI was marginally over, under or exactly the $28kg/m^2$ minimum BMI criteria for the study, potential participants were informed of this and given the option to continue with the screening, discontinue the screening or discontinue the screening and take accurate measurements using home scales and re-contact the study site if measurements were different from those previously provided. Participants who chose to continue

with the screening and met all other eligibility criteria were invited to attend the baseline appointment for the study with the understanding that if their BMI as measured at the study centre was below 28kg/m^2 they would be unable to continue with the trial.

Inclusion/Exclusion Criteria

The inclusion criteria for the WRAP trial were:

- Age ≥18 years old

- BMI ≥28 kg/m^2

- Willingness to adhere to the study requirements

The exclusion criteria were:

- Current engagement with a structured weight loss programme

- Current pregnancy or pregnancy planned within the next 2 years

- Previous bariatric surgery or surgery planned within the next two years

- Non-English speaking or inability to understand study materials written in English

2.3.5. Participants from the whole WRAP sample

Between the three study sites 1954 potential participants were screened for eligibility, resulting in 1269 participants being enrolled in the trial. At baseline, enrolled participants had a mean age of 53.21 years (*SD* 13.66 years) and a mean BMI of 35.54 kg/m^2 (*SD* 5.12). The majority of the sample was female (67.8%) and self-identified as White-British (83.1%). When asked about their employment status,

the most frequently selected response made by participants was "Employed by other" (47.5%). Participants reported a modal household income of £10,000-£19,999 per annum (17.7%).

2.3.6. Sample available for analysis

Chapter 3 analysed weight, BMI and PFS total score data from WRAP trial participants. Not all participants provided complete data (PFS and/or weight) at each time point of the WRAP trial.

BMI and PFS data was available for 1230 of 1269 WRAP trial participants at 0 months (baseline), however the amount of data available decreased at each subsequent trial visit. This is to be expected with longitudinal trials and was due to participants not completing the PFS, missing a trial visit or withdrawing from the study. Due to the somewhat large decrease in available, complete data between the 0 and 24 month visit (N=1269 at 0 month to n= 594 at 24 months) a completers only analysis approach was adopted for each hypothesis to be analysed, rather than missing value replacement or Intention to Treat, to avoid the risk of such a large amount of data imputation masking any significant statistical effects. Data were counted as "complete" for each hypothesis to be tested if PFS score and BMI were available for all time points included in that analysis. It should also be noted that some participants missed a follow-up visit or did not provide PFS data at one time point but provided this data at a subsequent visit. In these cases the participant's data was included up to the point that they provided complete PFS and BMI data.

2.3.7. Number of Weight Watchers Meetings Attended

Data regarding the number of Weight Watchers meetings that the participants attended was collected by linking participants to voucher codes, however this data is not available for analysis due to a computing error within Weight Watchers' data monitoring facilities.

2.3.8. Design and Data Preparation

The investigations described in Chapter 3 follow a mixed design: participants were assigned to one of three intervention groups and all participants completed the same measurements at each time point. For analyses that consider only 0 and 3 month data the two commercial provider interventions groups (CP12 and CP52) are collapsed in to one commercial provider (CP) group. This is because between 0 and 3 months of the WRAP trial participants in the CP12 and CP52 arms had all received 12 weeks of Weight Watchers vouchers and, until the 3month point in the WRAP trial, had effectively received the same intervention.

2.3.9. Fasting Status and PFS Scores

Due to the design of the WRAP trial, fasting state at the times that participants completed the Power of Food Scale could not be controlled between sites and visits. At 0 and 12 month visits participants who opted to provide a blood sample were instructed to arrive in a fasted state, having consumed nothing other than water for at least 12 hours. Conversely, participants who chose not to provide a blood sample were not required to fast before these visits. The 3 month study visit did not involve any fasted measures, so no participants were instructed to fast

before they attended these visits. Furthermore, at the 0 month visit some participants chose to take the PFS away to complete at home, whereas other completed the PFS during the visit. Shortly before the 3, 12 and 24 month visits participants received a questionnaire pack containing the PFS in the mail and were encouraged to complete the questionnaires before attending the visit, however some chose to complete the questionnaires during their visit to the study centre.

In order to assess the potential impact of fasting prior to venepuncture on hedonic hunger, differences in PFS scores between fasted and non-fasted participants were assessed. Fasting status was probed prior to venepuncture at the 0 month visit, however not all participants who fasted proceeded to provide a blood sample. Furthermore, no record of fasting status was made for participants who indicated during screening that they would not provide a blood sample, although anecdotal reports from the Liverpool WRAP site indicated that some of these participants mistakenly fasted for their baseline visit. As such, fasting status needed to be deduced from visit notes on a participant-by-participant basis. This was carried out initially using only 0 month data from the Liverpool site. If significant difference in PFS scores between fasted and non-fasted participants was found this analysis would be extended to include data from the 12 month WRAP visit. If significant differences were found in this second analysis data from the whole WRAP sample would have been coded and analysed. If significant differences were found across the whole sample fasting status would be used as a covariate in subsequent analyses.

Fasting data coding

82

Before coding took place Liverpool site data was retrieved for baseline and 12 month visits. Five hundred and forty two visit records were retrieved, of which fasting status was recorded for 281 visit records; no fasting status was recorded for 261 records.

Database entries for each blank record were checked for notes to indicate fasting status. The following judgments were made:

- 53 records deemed fasted (41 baseline visit, 12 12 month visit)
- 113 records deemed not fasted (62 baseline visit, 51 12 month visit)
- 95 deemed unclear (52 baseline visit, 43 12 month visit)

To arrive at the three possible judgements (fasted, not fasted or unclear) information from the WRAP database for each participant and visit was reviewed. Fasting judgement categories and related assumptions were made based on the information contained in the WRAP database (see Table 2.1).

Fasting Status Analysis

Data from Liverpool participants for whom a fasting status could be deduced, who had attended the 0 month visit and completed the Power of Food Scale was submitted to a Mann-Whitney test. This was to assess if there was a difference in Power of Food Scale Total Scores between participants who attended the baseline visit and completed the PFS in a fasted state (fasted participants) and those who attended the baseline visit and completed the PFS in a non-fasted state (non-fasted participants). Results showed PFS Total scores in fasted participants (*Mdn* = 2.67) did not differ significantly from PFS Total scores in non-fasted participants (*Mdn* =2.70), *U* =4136.00, *z* = -.162, *p*=.872, *r* = -0.01. This lack of

difference in PFS total scores between fasted and non-fasted participants suggests that fasting for a minimum of 12 hours did not alter responses to the PFS in Liverpool participants at the baseline visit. From this, the decision was taken not to further probe fasting status in the 12 month visit date or the wider WRAP sample, and not to include fasting status as a covariate in further analyses of PFS data from WRAP participants.

Table 2.1 Fasting judgement categories and related assumptions were made based on the information contained in the WRAP database.

Category	n	Judgement	Assumptions/Justification
Blood not taken	95	Unsure	The database records indicate that the participant consented to providing a blood sample but no blood was taken and no reason for this is recorded.
Diabetic	1	Not fasted	Participant unable to fast due to diabetes.
GP advised no blood	1	Not fasted	Participant advised by GP not to give a blood sample, so assume participant did not fast for the visit.
Afternoon appointment	3	Not fasted	Blood samples were not taken in afternoons at the Liverpool site due to the length time participants would be required to fast for. It is assumed that participants choosing afternoon appointments would be made aware that they did not have to fast as they would not be providing a blood sample.
Friday appointment	6	Not fasted	Blood samples were not taken on Fridays at the Liverpool site because the Cambridge site could not receive posted blood samples over the weekend. It is assumed that participants choosing Friday appointments would be made aware that they did not have to fast as they would not be providing a blood sample.
Arrived unfasted	33	Not fasted	Notes in the visit form in the WRAP database indicate that the participant arrived for their visit in an unfasted state due to forgetting or not wanting to fast.
Did not consent to bloods	69	Not fasted	Participant did not consent to providing blood samples at the start of the study. As fasting was required for blood samples, it is assumed that participants would not have arrived for the visit fasted if they did not intend to give blood.
Notes indicate fasted	4	Fasted	Although blood was not taken, notes on the participant's database record indicates that they arrived for the visit fasted.
Failed blood sample	49	Fasted	Notes on the participant's database record indicated that an unsuccessful venepuncture attempt was made. As an attempt to take a blood sample was made, it is assumed that the participant arrived to the visit fasted.

2.3.10. Published results of the WRAP trial

The results of the WRAP trial regarding the clinical and cost effectiveness of referral to an open group behavioural weight management programme for weight loss (Weight Watchers) have been described by Ahern et al. (2017). Results showed that, at the 3 month WRAP trial visit, participants in the WW12 and WW52 intervention arms lost more weight than those in the BI. At 12 months, participants in WW12 had lost more weight than those in BI, and participants in WW52 had lost more weight than both WW12 and BI. At 24 months some weight had been regained in by participants in each intervention arm, but the pattern of results was the same as at 12 months. Ahern et al (2017) concluded that referral to Weight Watchers for 12 weeks or more produced greater weight loss than a brief, self-help intervention, and referral to Weight Watchers for 52 weeks produced the greatest weight loss and was more cost-effective when results were modelled over 25 years. These findings show that each intervention arm of the WRAP trial was successful in inducing weight loss in adults with overweight and obesity, and that referral to Weight Watchers produced superior results than a brief, self-help intervention. The work presented in Chapter 3 extends that of Ahern et al. by exploring the relationship between hedonic hunger and weight loss during the WRAP trial.

2.4. Questionnaire measures

2.4.1. The Power of Food Scale (PFS)

The Power of Food Scale (Appendix 5; Cappelleri et al., 2009; Lowe et al., 2009) is a validated fifteen item self-report measure assessing the effects of the food environment on motivation to consume palatable food. The PFS is the only published, validated tool for measuring hedonic hunger. Items describe appetite for, but not actual consumption of, palatable food at three levels of proximity – food availability in the wider environment, food that is physically present, and food that is tasted but not yet consumed. Items are rated on a 5-point Likert scale anchored 1 – "Don't agree at all" to 5 – "Strongly agree" The total score for the PFS is an aggregate of scale items and represents the score for hedonic hunger. Possible scores range 1-5, with higher scores indicating higher hedonic hunger. The PFS exhibits good reliability (α=.91) and four-month test-retest reliability in an adult population (Lowe et al, 2009). The PFS was used to assess hedonic hunger in Chapter 3-5.

2.4.2. Medical History Questionnaire (Appendix 8)

This questionnaire was used to screen participants for food allergies and general health in Chapter 5. This questionnaire asks participants to report previous adverse reactions to foods/ingredients, to report foods they choose not to eat, and includes a list of foods/ingredients that are commonly associated with food allergies or intolerances. Participants were asked to indicate if they have ever consumed and ever had an adverse reaction to any of the foods listed. Participants who reported

previous adverse reactions to foods or ingredients that were contained in the study foods would have been excluded from the study. No participants included in the study in Chapter 5 reported any adverse reactions to any of the foods or ingredients listed.

2.4.3. Chocolate Consumption Questions (Appendix 9)

This questionnaire was used to assess chocolate consumption in Chapter 5. Participants were asked to report their chocolate consumption for the seven days before and the seven days following the study. The Participant Information Sheet (Appendix 10) informed participants that part of the study required them to write down how much of one of the five snack foods (chocolate, cake, biscuits, potato crisps or chips) they had consumed over the previous seven days. This was necessary to disguise that the study was interested primarily in chocolate consumption.

Participants were informed when they made an appointment to attend their first laboratory session for the study that they would be asked to write down how much chocolate they had consumed over the previous seven days and advised that they may wish to keep a note of this if they thought it would be difficult for them to recall. During the first and second laboratory session participants reported their recalled chocolate consumption on paper (Chocolate Consumption Questionnaire, Appendix 9). At the seven day follow-up this was done via online survey. The Chocolate Consumption Questionnaire used in this study has not been previously validated but was designed to be a similar tool to the Timeline Follow-back drinking diary (TLFB; Sobell & Sobell, 1992). The TLFB measures self-reported alcohol

consumption over the preceding 7 or 14 days, and frequency or the amount of alcohol (in units) the respondent consumed can be calculated. In the current study the similar principle of reported chocolate consumption over the preceding 7 days was used to estimate chocolate consumption frequency.

2.4.4. Visual Analogue Scale (Appendix 11)

Hunger was assessed using a paper-based Visual Analogue Scale (VAS). Participants marked a 100mm line (anchored "Not at all hungry/Extremely hungry") to indicate their hunger. This question was embedded amongst other VAS items assessing mood, alertness, thirst etc. to disguise the purpose of the questionnaire. This questionnaire was used to assess hunger at Chapter 5.

2.5. Laboratory Assessments

2.5.1. Height and Body Weight

Height was measured with shoes removed using a floor-mounted stadiometer (Leicester Height Measure, Marsden Group, UK). Body weight was measured to the nearest 100g in street clothing with shoes removed using floor-mounted digitally calibrated electronic scales (seca 888 Class (III) Floor Scale, seca, UK). Measurements were taken in the same laboratory as all other study procedures. These procedures were used to assess height and weight in Chapter 3-5. Body Mass Index (BMI) was calculated as body weight in kilograms (kg) divided by to height in metres squared (m^2) from assessments of height and weight.

2.5.2. Chocolate Taste Test

Participants enrolled in the study described in Chapter 5 did so under the impression that they would be asked to taste "up to two of the five foods listed in the Participant Information Sheet" (see Appendix 10) at either of the two laboratory sessions, although only chocolate and potato crisp consumption were assessed in the study. Ad libitum chocolate consumption was covertly measured under the guise of a taste test. This is commonly used in similar research and has recently been validated and an effective method of measuring laboratory food intake (Robinson et al., 2017). Participants were presented with a bowl of 200g milk chocolate buttons (Figure 2.2; Cadbury Dairy Milk Giant buttons, 530kcal per 100g; 5.3kcal per 1g) and instructed to eat as much or as little as they liked in order to rate the chocolate on a range or variables such as "smoothness", "sweetness" and "lightness". Ratings were made on a 100mm Chocolate VAS (Appendix 12). The amount of chocolate consumed during the taste test was calculated by weighing the bowl containing the food before and after the taste test. Bowls and food were weighed to the nearest .1g. The difference in weight indicated the amount of food eaten by the participant. Calories consumed were calculated by multiplying the number of grams of food consumed by the number of calories in 1g of the food. Consumption was measured by comparing weight measurements for the bowl of food before and after the taste test. The taste test paradigm is widely used in both research directly related to ABR (e.g. Kemps et al., 2015) and the wider appetite research field (e.g. Higgs, Williamson, & Attwood, 2008).
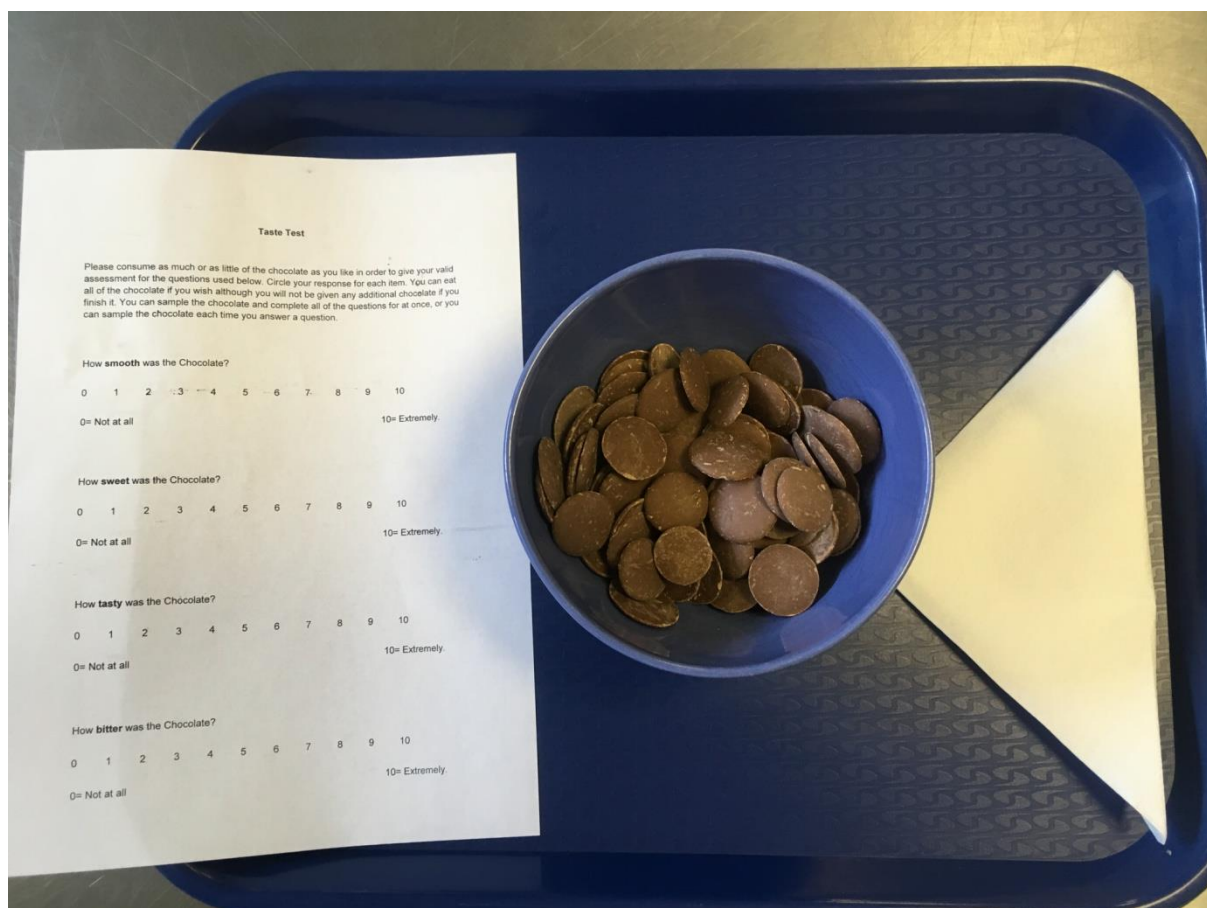
Figure 2.2 Photograph of chocolate taste test.

2.5.3. Potato Crisps Taste Test

The potato crisps taste test was used in Chapter 5. Ad libitum potato crisp consumption was covertly measured under the guise of a "taste test". Participants were presented with a bowl of 75g salted potato chips (Figure 2.3; Walkers Ready Salted crisps, 526kcal per 100g; 5.26kcal per 1g) and instructed to eat as much or as little as they liked in order to rate the chocolate on a range or variables such as "saltiness", "crunchiness" and "lightness". Ratings were made on a 100mm Potato Crisp VAS (Appendix 13). Consumption was measured by comparing weight measurements for the bowl of food before and after the taste test, as in the chocolate taste test.
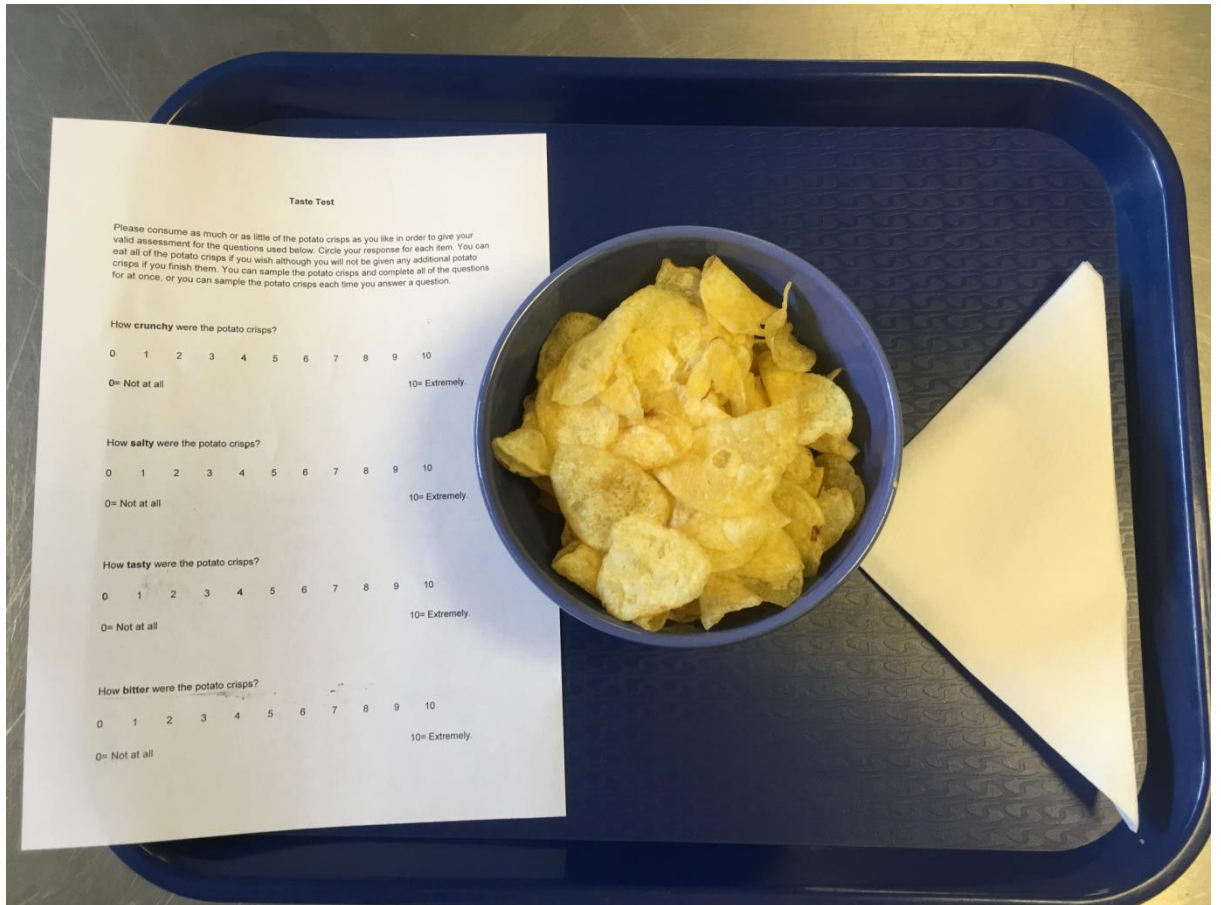
Figure 2.3 Photograph of potato crisp taste test.

2.6. Attentional Bias Measures

Chapters 4 and 5 measured attentional bias (AB) using a computerised visual probe task with concurrent eye movement recording. The description of the visual probe task and attentional bias retraining intervention used in Chapter 5 are presented within that chapter. The same computer and eye-tracking equipment was used in both studies.

The visual probe task was chosen as a method of measuring AB due to its superiority over the Stroop task in assessing approach and avoidance related responses to stimuli (Hardman et al., 2017). The visual probe task compares reaction time (RT) responses to probes which replace images of critical stimuli to probes which replace neutral stimuli. Eye movement recordings allow measuring of fixation time on critical versus neutral stimuli. An overview of the rationale of the visual probe is presented in Section 1.6.5.1.

2.6.1. Chapter 4 Visual Probe Task

The visual probe task in Chapter 4 assessed AB to high and low calorie stimuli. During the visual probe task trials began with a fixation cross that remained onscreen for 500ms. Following this participants were presented with stimulus displays of two colour images that remained on screen for 2000ms. Images measured approximately 125mm wide by 100mm high and were placed 600mm apart on screen. The stimulus display was replaced by a small arrow in the location of one of the pictures. Participants responded to the direction the arrow pointed (up/down) by making a spatially compatible keypress on a standard QWERTY

keyboard. An inter-trial-interval of 500ms followed the participant's response before the next trial began with the fixation cross.

Participants completed 10 practice trials that used neutral images to ensure familiarity with the task instructions. Following this, participants completed 2 buffer trials using neutral images from the practice trials, followed by 160 experimental trials organised in to 4 blocks of 40 trials each. Experimental trials comprised 128 critical trials and 32 filler trials. Each food image was displayed with a neutral image 4 times. An additional 8 neutral images were displayed four times each to create the filler trials. Food images appeared on the left and right side of the screen equally often. The probe replaced the food image and neutral image with equal frequency. Trials were presented in a new random order for each participant.

2.6.2. Calculation of Attentional Bias Scores

The combined use of a visual probe task with concurrent eye-movement recording in Chapters 4 and 5 permitted calculation of indirect reaction time (RT) measures of AB and direct, gaze dwell bias (GD AB) indices. The data preparation and AB calculation methods described below were used for data from Chapter 4 and 5.

Prior to analysis, reaction time (RT) data were subjected to trimming procedures similar to those used by Christiansen et al. (2015) and Lattimore and Mead (2015). Before trimming began, a missing data threshold of 10% was decided, whereby any participant losing more than 10% of their RT data from trimming would be removed from analyses. RTs faster than 200 milliseconds (ms) and slower

than 2000ms, RTs beyond 2.5 standard deviations of each participant's mean RT and trials on which errors were made were removed prior to analysis. No participant breached the missing data threshold and RT data from all participants was retained for analyses. RT bias was calculated by subtracting mean RT on trials where the visual probe replaced the food cue from mean RT from trials where the visual probe replaced the neutral cue. Positive scores indicate AB.

Gaze dwell times (the length of time participants fixated on either the food or non-food image) for food and control images were extracted from eye movement recordings. Gaze dwell times represent the total amount of time (in ms) participants fixated on the food cue and the neutral cue. Gaze dwell bias is the difference between these two measures. Eye movements were classed as a fixation if they remained stable for at least 100ms and within one degree of visual angle. Gaze dwell bias was calculated by subtracting dwell time on neutral images from dwell time on food images. These parameters are identical to those used in Christiansen et al (2015), who employed a similar task design to that used in the current thesis.

2.6.3. Stimuli Used in the Attentional Bias Tasks

Colour image stimuli were used in the visual probes tasks in Chapters 4 and 5. Image stimuli were selected to be clearly representative of a food or neutral items and matched for image complexity and general colour. All stimuli were presented against a black background. Chapter 4 assessed AB for high and low calorie food images. Chapter 5 assessed AB to chocolate images. For clarity, stimuli for each chapter will be discussed separately.

Stimuli for Chapter 4 Visual Probe Task

Three types of images were used in the visual probe task: high calorie food images (8 images), low calorie food images (8 images) and matched neutral images. An additional 10 images that represented neutral items were selected for use in practice trials. Stimuli for this task were selected from stimuli used by Lattimore and Mead (2015), from images used by other researchers at the University of Liverpool, and from the *food-pics* image database (Blechert, Meule, Busch, & Ohla, 2014). The *food-pics* image data base is a freely available database of photographs of food and neutral items that are designed for use in research. Images in the database are photographed against a neutral background with balanced shadowing. Examples of the stimuli used in this task are shown in Appendix 14.

Stimuli for Chapter 5 Visual Probe Task

Stimuli for the Chapter 5 visual probe task were 8 images of chocolate and 8 neutral images. Images were selected from those used for Chapter 4 and the *food-pics* database (Blechert et al., 2014). Examples of the stimuli are shown in Appendix 15.

2.6.4. Hardware/Software for the Visual Probe Tasks

The same hardware and software were used for the visual probe tasks in Chapter 4 and 5. Both studies were conducted from the same laboratory.

The visual probe tasks used in Chapters 4 and 5 were both programmed in Inquisit 3.0.6.0: Inquisit (Millisecond Software, 2011). All on-screen instruction text was presented in Arial 14pt. Fixations crosses were Arial, 64pt.

Eye movement recording was carried out using an Eye-Trac D6 (Applied Science Laboratories, Bedford, MA) eye tracker. The sampling rate was 120Hz. Gaze direction was measured in degrees, once every 8.5ms, dwell times were defined as eye movements stable to within 1° of the visual angle for at least 100ms.

2.7. Participant Recruitment – Chapter 4

Participant recruitment for Chapter 4 occurred in two streams. The initial intention was to recruit all participants for this study from Liverpool site of the WRAP trial. However, recruitment was not as successful as hoped so the recruitment procedure was widened to include community-dwelling participants. The two recruitment streams are detailed below.

WRAP Participant Recruitment

WRAP participants were recruited from the commercial provider (WW12 and WW52) arms of the WRAP trial at the Liverpool site WRAP participant database.

Eligibility criteria were identical to those required by the WRAP trial plus the following exclusion criteria:

- Age above 60 years at recruitment

- Impaired or uncorrected vision. Participants who have corrected vision through the use of spectacles or contact lenses will not be excluded from the study.

- Diagnosis of diabetes

- Current use of antidepressants

- Current use of medications to control or known to affect appetite or weight

- Vegetarian/vegan or another dietary restriction

- Unable to attend a T1 appointment for the study in the days between the baseline visit for WRAP and their first Weight Watchers meeting.

Participants who were identified as aged 60 years or under, randomised to a commercial provider group for the WRAP trial and who consented to being contacted regarding future studies beyond the WRAP trial were offered information about the study. This was carried out by the researcher running the baseline appointment for the WRAP trial. The researcher briefly explained the study to the participant using the Study Overview Script (Appendix 16). Interested participants were offered the Participant Information Pack consisting of a Participant Invitation Letter, Participant Information Sheet and Consent Form (Appendix 17) for the study and asked if they would be willing to be contacted for a follow up call relating to the study 24 hours later. During this telephone call participants were screened for eligibility using Study Telephone Screening Script (Appendix 18) and, if suitable, participants were invited to attend the study.

Community-Dwelling Participant Recruitment

Participants were recruited from the general Merseyside population by study advertisements and snowball sampling. Advertisements (see Appendix 19 for example) were placed around the University of Liverpool campus and surrounding areas. Interested participants were provided with a Participant Information Sheet (Appendix 20). Participants were screened for eligibility (Telephone Screening Script, Appendix 21). Eligibility criteria were identical to those applied to WRAP participants.

All study procedures were identical for participants recruited from the two recruitment streams with two exceptions. Community-dwelling participants were provided with a Weight Watchers referral pack identical to those used in the WRAP trial (Figure 2.1) during their first laboratory session for the study. Community-dwelling participants also completed a different Consent Form (Appendix 22).

All participants received a £30 honorarium for their time, plus travel expenses.

2.8. Participant Recruitment – Chapter 5

Participants were recruited for the study described in Chapter 5 from the staff and student population of the University of Liverpool and local community via advertisements and word of mouth. An example study advertisement is shown in Appendix 23. Advertisements directed participants to an online screening questionnaire where they were presented with the Participant Information Sheet (Appendix 10). Participants deemed eligible for the study were invited to attend the laboratory. Informed consent was taken at the laboratory (Appendix 24).

2.9. Ethical Approval

All studies detailed in this thesis had received ethical approval from the University of Liverpool Research Ethics Committee. No study procedures were carried out prior to ethical approvals being granted.

Chapter 3 - The role of hedonic hunger in weight change during and following a behavioural weight loss programme

3.1. Introduction

Chapter 1 identified that there is, theoretically, a role played by hedonic hunger in weight loss. The growing body of literature surrounding hedonic hunger suggests that it is related to appetitive constructs relevant to dieters (Section 1.4), and may be a barrier to weight loss success and is reduced with weight loss (Section 1.5). However, some literature implies that hedonic hunger is not predictive for future BMI change in female undergraduates (Finlayson, Cecil, Higgs, Hill, & Hetherington, 2012) and young (age 20) US adults (Lipsky et al., 2016). There is limited available evidence that tracks the stability of hedonic hunger throughout extended time periods. There is also limited understanding of the relationships between hedonic hunger and BMI during the course of weight management; that is, pre-intervention, during weight loss endeavours, and during weight loss maintenance. Exploration of the role of hedonic hunger in weight loss is the central theme of this thesis, and this chapter aims to provide evidence regarding how hedonic hunger changes during and following a behavioural weight management programme, how hedonic hunger is related to weight loss success, and the extent to which changes in hedonic hunger may be a mechanism by which behavioural programmes achieve weight loss.

Most studies on hedonic hunger and weight loss have focussed on bariatric surgery and intensive clinical interventions. The current study is an important

addition to the literature because it assessed the role of hedonic hunger in weight loss in adults participating in a commercial open-group behavioural weight loss programme (Weight Watchers), one of the most common forms of weight loss used globally (Weight Watchers, 2016) and in primary care in the UK (NICE, 2014).

This study was a part of the WRAP (Weight Loss Referrals for Adults in Primary Care trial; Ahern et al., [2014, 2017]). The WRAP trial (Section 2.3.9) investigated the clinical and cost-effectiveness of referral to a commercial weight management provider (Weight Watchers) for 12 weeks (WW12) or 52 weeks (WW52) compared with referral to a brief self-help intervention (BI). Results showed that the WW12 and WW52 groups combined produced significantly greater weight loss than the BI group at 12 and 24 months. WW52 produced superior weight loss to WW12 and BI at 12 and 24 months. When modelled over 25 years, WW52 was also more cost-effective than WW12 and BI. The current study assessed the role of hedonic hunger in the weight changes observed during the WRAP trial, and examined the effect of a behavioural weight management programme on hedonic hunger over time.

O'Neil et al. (2012) showed that hedonic hunger decreased in adults with overweight and obesity over the course of a 12 week referral to Weight Watchers, and that this was associated with increased weight control behaviour usage and greater weight loss. While this finding indicates that hedonic hunger plays some role in weight loss, this study did not examine the potential relationship between hedonic hunger and weight loss over a longer period of time. Moreover, O'Neil et al. did not include a comparison or control intervention, so the observed change in

hedonic hunger cannot be fully attributed to the weight management programme. The aim of this chapter was to use WRAP data to build upon work by O'Neil and colleagues (2012) by extending observations of hedonic hunger and weight over 24 months (before, during and following a behavioural programme) and to use autoregressive cross-lagged models to understand how these factors change together over time. By using a cross-lagged design, the effect of hedonic hunger and BMI at one point in time on hedonic hunger and BMI at subsequent time points, while controlling for any effects of baseline measures of these variables and potential covariates, was examined. In addition, the current study compared changes in hedonic hunger between intervention groups. This determines whether the Weight Watchers programme has an intervention-specific effect on weight change, and whether hedonic hunger moderates intervention effects on weight change.

3.1.1. Research Questions

1. The research questions addressed in this chapter were: *Is there a relationship between hedonic hunger and BMI at baseline, in this sample of overweight and obese treatment-seeking participants?*

2. *How do hedonic hunger and BMI change during and following a behavioural weight loss programme?*

3. *Does baseline hedonic hunger predict weight change at 3, 12 and 24 months (collapsed across interventions)?*

4. *Are changes in hedonic hunger associated with changes in weight over time (collapsed across treatment group)?*

5. *Do changes in hedonic hunger mediate the effect of the intervention of a behavioural weight loss programme on weight change?*

6. *Does baseline hedonic hunger moderate the effect of the intervention on weight change?*

3.2. Method

3.2.1. Participants and Procedure

One thousand, two hundred and sixty-nine participants were enrolled in the WRAP trial (Section 2.3), of which 1230 provided baseline BMI and Power of Food Scale (PFS) total score data. Missing data (n=39) was due to participants not completing the PFS at baseline. Only data from the 1230 participants who provided BMI and PFS total score at baseline are included in the analyses presented in this chapter.

The full recruitment and study procedures are described in Section 2.3, but are briefly presented here. Participants were recruited from 23 GP surgeries in England and randomly allocated to one of three intervention arms: referral to Weight Watchers for 12 weeks (WW12); referral to Weight Watchers for 52 weeks (WW52) or a brief, self-help intervention (BI). Participants in the trial attended four study visits at their local study centre (Liverpool and Cambridge) or GP surgery (Oxford) at baseline (0 months), 3, 12 and 24 months. At each visit participants provided a height (baseline only) and weight measure. At or shortly before each visit participants completed the PFS (Section 2.4.1).

3.2.2. Design and Data Preparation

The investigations described in this chapter follow a mixed design: participants were assigned to one of three intervention groups and all participants completed the same measurements at each time point. For analyses that consider

only baseline and three-month data the two commercial provider intervention groups (WW12 and WW52) are collapsed in to one commercial provider (WW) group. This is because participants in the WW12 and WW52 arms had all received 12 weeks of Weight Watchers vouchers between baseline and three months of the WRAP trial, and had effectively received the same intervention until the three month point in the WRAP trial.

Although BMI and PFS data were available for 1230 of 1269 WRAP trial participants at 0 months (baseline), the amount of data available decreased at each subsequent trial visit. This is to be expected with a weight management trial of this length and was due to participants not completing the PFS, missing a trial visit or withdrawing from the study. Due to the somewhat large decrease in complete data between the 0 and 24 month visit (n=1269 at 0 month to n= 594 at 24 months), a completers only analysis approach was adopted for each hypothesis to be analysed, rather than missing value replacement or Intention to Treat, in order to avoid the risk of such a large amount of data imputation masking any significant statistical effects. Estimated or missing data is also not suitable for bias corrected bootstrapping of indirect effects, so imputing missing data would compromise the analyses of baseline effects described in this chapter. To address this, data were counted as "complete" for each hypothesis to be tested if PFS score and BMI were available for all time points included in the analysis. It should also be noted that some participants missed a follow-up visit or did not provide PFS data at one time point but provided this data at a subsequent visit. In these cases, the participant's data was included up to the point that they provided complete PFS and BMI data.

3.3. Results

3.3.1. Participant Characteristics

The majority of participants were female (n=840). Participants had a mean age at baseline of 53.23 years ($s.d.$= 13.68) and a mean baseline BMI of 34.56kg/m^2 ($s.d.$=5.12). Mean baseline hedonic hunger score (PFS total score) was 2.75 ($s.d.$= 0.92). A series of one-way ANOVAs showed that participants were well matched for baseline age, BMI and PFS total score (all p's>.1) across intervention arms of the WRAP trial (Table 3.1).

Table 3.1 Mean (± standard deviation) baseline age, BMI and PFS total score for WW12, WW52 and BI arms of the WRAP trial.

Intervention arm	N	Age at baseline	Baseline BMI	Baseline PFS total score
WW12	514	53.60 (± 13.26)	34.70 (±5.39)	2.76 (±.91)
WW52	513	53.35 (±13.90)	34.42 (±5.05)	2.73 (±.92)
BI	203	52.25 (±14.18)	34.60 (±4.63)	2.81 (±.97)

3.3.2. Is there a relationship between hedonic hunger and BMI at baseline, in this sample of overweight and obese treatment-seeking participants?

To assess the relationship between baseline measures of hedonic hunger and BMI in the wider WRAP sample data were submitted to a Pearson's correlation. Results revealed a small but positive correlation between hedonic hunger and BMI (r= .12, p<.01), suggesting that higher hedonic hunger score is associated with a greater BMI. To explore this further, participants were split into high and low hedonic hunger groups by median split of baseline PFS total scores (*median*= 2.66) and the difference in BMI between the groups was examined. Participants in the high hedonic hunger group (n=604) had a mean PFS total score of 3.54 (*s.d.*=.57) and a mean BMI of 34.96 (*s.d.* = 5.21), whereas participants in the low hedonic hunger group (n=626) had a mean PFS total score of 1.99 (*s.d.* =.43) and a mean BMI of 34.17 (*s.d.* = 5.01). Participants in the high hedonic hunger group had significantly higher BMIs than those in the low hedonic hunger group (t(1228)=-2.69, p=.007, d=.-.15), but this effect was small.

3.3.3. How do hedonic hunger and BMI change during and following a behavioural weight loss programme?

Data from participants across all interventions who provided complete BMI and PFS total scores for the baseline, 3, 12 and 24 month visits (n=594; 345 female) were used to explore how hedonic hunger and BMI changed during and following a behavioural weight loss intervention and whether the changes in hedonic hunger and BMI were significantly different for different intervention groups (Figure 3.1).

Participants included in this analysis had a mean baseline age of 56.62 years (*s.d.* = 12.38) and a mean baseline BMI of 34.03kg/m^2 (*s.d.* = 4.98). Baseline PFS total score for this subsample was 2.69 (*s.d.* = .91).

Changes in hedonic hunger

Data were submitted to a 3 (treatment group: WW12, WW52 and BI) x 4 (time: PFS total scores at baseline, 3, 12, and 24 months) mixed ANOVA. Data violated the assumption of sphericity so Greenhouse Geisser corrected values are reported. The threshold for significance was *p*<.05.

Analysis revealed a significant main effect of time (*F(*2.961)= 42.55, *p*<.001, η_p^2 = .07). The effect of group and the group x time interaction were non-significant (*p*'s>.05). Bonferroni corrected post-hoc tests revealed that the main effect of time was driven by PFS total scores decreasing between baseline and 3 months: mean PFS total score (± standard error) at baseline = 2.69 (±.04) vs 3 months = 2.40 (±.40), *p*<.001). PFS scores at 12 (2.44, ±.04) and 24 months (2.45, ±.04) were significantly lower than at baseline (*p*'s<.001). PFS total scores at 3, 12 and 24 months did not significantly differ from each other (*p*'s>.05). This suggests that, across interventions, PFS scores reduced from baseline to 3 months and remained suppressed at the 3, 12 and 24 month visits, therefore hedonic hunger reductions from baseline to 3 months persisted throughout the weight loss and weight maintenance phase of the WRAP trial, but this effect was not specific to any intervention arm. Mean PFS total scores over time collapsed across treatment groups are shown in Figure 3.2.

Changes in BMI

Data were submitted to a 3 (Treatment group: WW12, WW52 and BI) x 4 (time: BMI at baseline, 3, 12, and 24 months) mixed ANOVA. Data violated the assumption of sphericity so Greenhouse Geisser corrected values are reported. The threshold for significance was $p < .05$.

Analysis revealed a significant main effect of time ($F_{(1.67)} = 128.71$, $p < .001$, $\eta_p^2 = .18$). The main effect of group was non-significant ($p > .05$). The interaction between time and group was significant ($F_{(3.33)} = 10.26$, $p < .001$, $\eta_p^2 = .03$). Bonferroni corrected post-hoc tests revealed that this was driven by group differences in BMI occurring at the 12 month visit of the WRAP trial. At this point mean BMI (± standard error) for participants in the WW52 intervention arm was $30.87kg.m^2$ (±.32), which was significantly lower than mean BMI in the WW12 intervention arm (32.12, ±.33, p=.02) and the BI intervention arm (32.74 ±.58, p=.01). The difference in mean BMI between WW12 and BI at 12 months was not significant ($p > .05$). This suggests that the effect of intervention arm on BMI is evident at the 12 month point of the WRAP trial, with participants in WW52 having lower BMI than those in WW12 and BI, and there is no difference in BMI between BI and WW12.
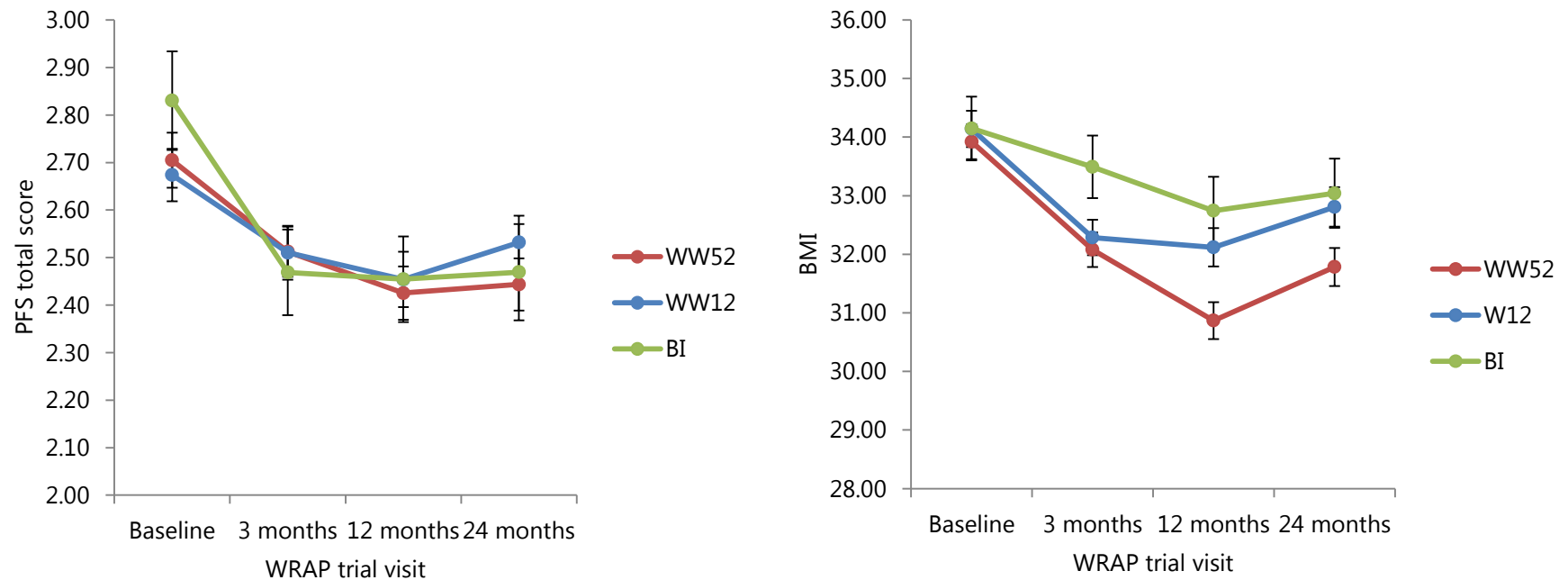
Figure 3.1 Mean PFS total score (a, left) and BMI (b, right) at each time point for each intervention of the WRAP trial. Error bars represent ±1 standard error. N = 594. WW52: 52 weeks Weight Watchers; WW12: 12 weeks Weight Watchers, BI: Brief Intervention.
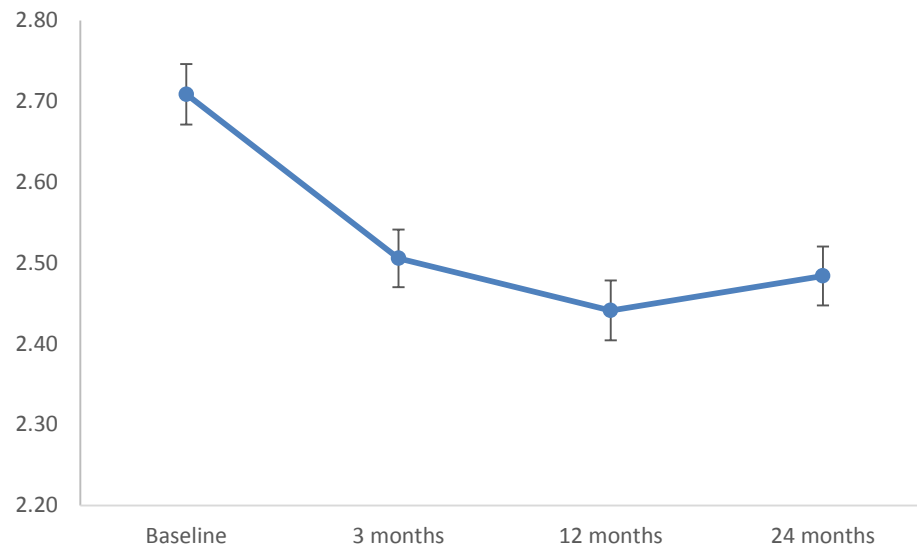
Figure 3.2 Mean PFS total score at each time point of the WRAP trial, collapsed across intervention arms. Error bars represent ±1 standard error. N = 594.

3.3.4. Relationship between hedonic hunger and BMI over time

Autoregressive cross lagged model

An autoregressive cross lagged model was used to examine the relationships between hedonic hunger levels and BMI over time at each follow-up visit across all intervention groups. The hypothesised model included PFS total score and BMI from the baseline, 3, 12 and 24 month WRAP trial visits. Age at baseline and gender were also included in the model as covariates. The proposed model was tested using multiple model fit indices to ensure the hypothesised model was a good fit to the data. The standardised root mean residual (SRMR) fit index, comparative fit index (CFI), incremental fit index (IFI), normed fit index (NFI) and root mean square error of approximation (RMSEA) were used to assess model fit. Criteria for determining acceptable model fit were as follows: SRMR values <.08 indicate a good fit; CFI ≥.95 indicates a good fit (Hu & Bentler, 1999); IFI >.90 indicates a good model fit (Bollen,1989); NFI >.95 shows a good model fit (Bentler & Bonett, 1980); RMSEA ≤.08 indicates a good model fit (Browne & Cudeck, 1992). Significance of direct and indirect effects within the model were accepted if $p<.05$.

Only data from participants who provided PFS total scores and BMI at baseline, 3, 12 and 24 month appointments was used to test the model, resulting in a sample size of $n=594$ for this analysis. The tested model and significant B values for direct effects are displayed in Figure 3.3 below. Age at baseline and gender were entered in to the model as covariates. Exploratory data analysis of effects found in

the model was carried out using the PROCESS macro (version 2) for SPSS (Hayes, 2013).

Inspection of model fit indices demonstrated that the tested model gave an excellent fit to the data. Although the RMSEA value was beyond the acceptable range (RMSEA = .19), other indices of model fit were excellent (CFI =.95; IFI =.95; NFI =.95; SRMR =.048). Figure 3.3 shows the hypothesised model and highlights significant direct effects in red. For clarity, results are discussed in relation to the two research questions addressed by this analysis.

The effect of age and gender on all measures at all time points was controlled for. Age was a significant predictor of hedonic hunger at 3 months (B = -.06, SE = .03, p=.035) and at 24 months (B = -.09, SE = .03, p=.003), and of BMI at 12 months (B = -.05, SE = .02, p=.005). Gender was a significant predictor of BMI at 12 months (B = .13, SE = .04, p<.001). The effects of age and gender at all other measures at other time points were not significant.

3.3.5. Does baseline hedonic hunger predict weight change at 3, 12 and 24 months (collapsed across interventions)?

Analysis of the effect of baseline hedonic hunger on weight at 3, 12 and 24 months yielded null results. The pathway between baseline hedonic hunger and BMI at 3 months was not significant (B=.004, SE = .029, p=.893, CI_{95} = -.02 to .02), implying that baseline hedonic hunger did not predict BMI at the 3-month WRAP trial visit. Bias corrected bootstrap confidence intervals were calculated to explore the indirect effects of baseline hedonic hunger on BMI at 12 and 24 months. The

indirect effect of baseline hedonic hunger on BMI at 12 months was not significant

(B=.032, SE =.020, p=.129, CI_{95} = -.002 to .063). Baseline hedonic hunger did not

predict BMI at 24 months (B=.031, SE = .019, p=.099, CI_{95} = -.001 to .064).
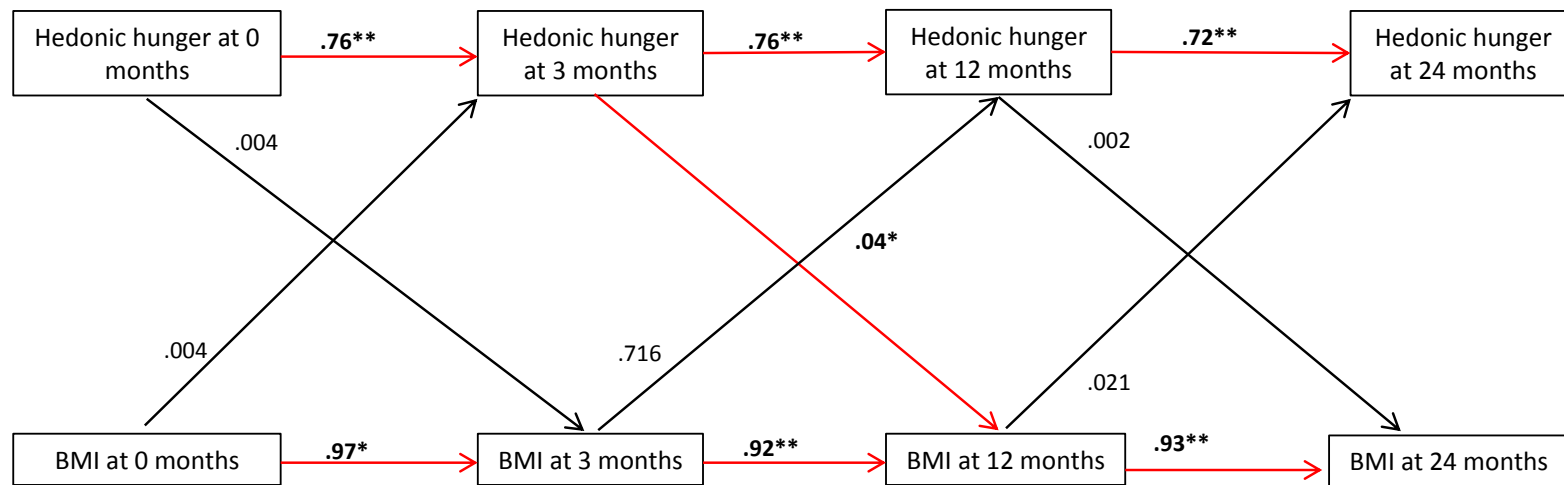
Figure 3.3 Structural model of the relationships between hedonic hunger and BMI at 0, 3, 12 and 24 months (standardized regression coefficients reported). Covariates (age at baseline and gender) and error terms not shown for clarity. Significant pathways are marked in red. Pathways marked * were significant at *p*<.05; those marked ** were significant at *p*<.001. Pathways marked in black were non-significant.

3.3.6. Are changes in hedonic hunger associated with changes in weight over time (collapsed across treatment group)?

Cross-lagged pathways between hedonic hunger and BMI at baseline, 3, 12 and 24 months were inspected to assess whether changes in hedonic hunger were associated with changes in BMI over the course of the WRAP trial. The only significant cross-lagged pathway to emerge was the effect of hedonic hunger at 3 months on BMI at 12 months (B=.04, SE=.02, p=.030, CI_{95} = .72 to .80). This means that, after controlling for variance associated with BMI at 3 months, hedonic hunger at 3 months predicted BMI at 12 months. Specifically, a higher hedonic hunger score at 3 months is predictive of a higher BMI at 12 months.

Results showed that hedonic hunger at baseline predicted hedonic hunger at 3 months (B=.76, SE=.03, p<.001, CI_{95} = .71 to .82). Hedonic hunger at 3 months predicted hedonic hunger at 12 months (B=.76, SE=.03, p<.001 CI_{95} = .72 to .80). Hedonic hunger at 12 months predicted hedonic hunger at 24 months (B=.72, SE=.02, p<.001, CI_{95} = .64 to .77). BMI at each visit was also predictive of BMI at the subsequent visit. BMI at 0 months predicted BMI at 3 months (B=.97, SE=.01, p<.001, CI_{95} = .95 to .99). BMI at 3 months predicted BMI at 12 months (B=.92, SE=.02, p<.001, CI_{95} = .90 to .95). BMI at 12 months predicted BMI at 12 months (B=.931, SE=.014, p<.001).

3.3.7. Do changes in hedonic hunger mediate the effect of the intervention of a behavioural weight loss programme on weight change?

Because the interventions did not have a direct effect on hedonic hunger, the assessment of changes in hedonic hunger mediating the effect of the programmes on weight change was not examined.

3.3.8. Does baseline hedonic hunger moderate the effect of intervention on weight change?

Moderation analyses

A series of moderation analyses were conducted to investigate how different levels of baseline hedonic hunger moderated the effect of intervention on BMI change. These analyses considered BMI change during the initial weight loss period and BMI change over 12 months. Moderation analyses were conducted using the PROCESS macro for SPSS (Hayes, 2013). Levels of hedonic hunger were defined as low, medium and high using PFS total scores. Low represented 1 standard deviation below the mean, medium represented the mean, and high represented 1 standard deviation above the mean. Models examined how levels of hedonic hunger moderated the effect of the intervention on BMI change. Interventions were compared to each other. A schematic of the hypothesised model tested each time is shown in Figure 3.4.

```
┌──────────────┐                                              ┌──────────────┐
│      X       │                                              │      Y       │
│ Intervention │─────────────────────────────┐                │  BMI Change  │
│              │                              │───────────────▶│              │
└──────────────┘                              ▲                └──────────────┘
                                              │
                                       ┌──────────────┐
                                       │      M       │
                                       │   Hedonic    │
                                       │    hunger    │
                                       └──────────────┘
```
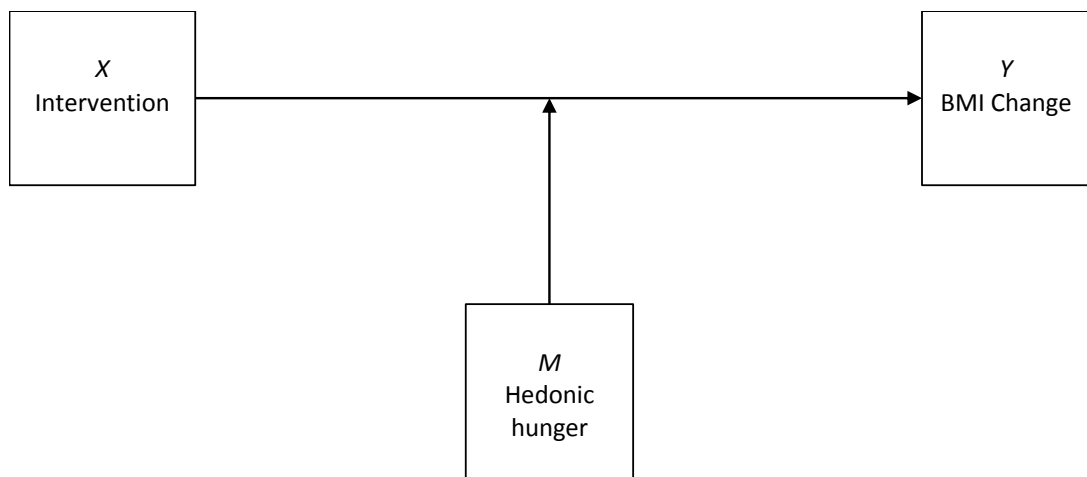
Figure 3.4 Schematic of the hypothesised moderation model tested throughout section 3.3.8

BMI Changes between baseline and 3 months

Baseline hedonic hunger was examined as a moderator of the relationship between intervention and BMI change between baseline and 3 months. To explore the effect of specific intervention (BI, WW12, and WW52) and any interaction of this with hedonic hunger, analyses compared each intervention to the other. Although WW12 and WW52 were the same intervention between baseline and 3 months, this comparison is included here to confirm the suggested intervention similarity and for consistency.

Model 1 assessed how the effect of intervention (WW12 vs BI) on BMI change between baseline and 3 months was moderated by hedonic hunger. Data from 328 (205 female) participants was included in this analysis. Participants in this sample had a mean baseline age of 56.57 years (*s.d.* 12.47), mean baseline BMI of 34.14kg/m^2 (*s.d.*=4.81) and a mean baseline PFS total score of 2.71 (*s.d.*=.89). The overall model was significant R^2 = .13, F(3, 324) = 17.03, p<.001, however neither hedonic hunger nor intervention were significant predictors of BMI change (p's>.05).

The interaction between hedonic hunger and intervention[1] was also non-significant (*p*>.05).

Model 2 assessed how the effect of intervention (WW52 vs BI) on BMI change between baseline and 3 months was moderated by hedonic hunger. Data from 346 (242 female) participants were included in this analysis. Participants in this sample had a mean baseline age of 56.02 years (*s.d.*=12.69), mean baseline BMI of 33.97kg/m^2 (*s.d.*=4.73) and a mean baseline PFS total score of 2.73 (*s.d.*=.94). The overall model was significant R^2 = .14, $F(3, 342)$ = 18.87, *p*<.001. Intervention type and hedonic hunger were not significant predictors of BMI change (*p*'s>.05). The interaction between hedonic hunger and intervention was also non-significant (*p*>.05).

Model 3 assessed how the effect of intervention (WW12 vs WW52) on BMI change between 0 and 3 months was moderated by hedonic hunger. Data from 514

---

[1] These findings are in contrast to those of the main WRAP trial results (Ahern et al, 2017), which showed greater BMI reduction in WW12 than BI between baseline and 3 months. The explanation for this is statistical. The 328 participants included in this analysis represent a subset of the data analysed by Ahern et al. Only data from participants who provided BMI and PFS scores at baseline and 3 months of the WRAP trial were included here, whereas Ahern et al. considered data from all participants enrolled in the trial in their analysis, thus reducing the statistical power of Model 1 compared to that of Ahern et al. Furthermore, Model 1 controlled for baseline hedonic hunger and the interaction between baseline hedonic hunger and intervention arm and, because they were a product of one another, these variables were collinear. When these variables are not controlled for the results mirror those of Ahern et al. in that participants in WW12 showed a significantly greater BMI reduction (-1.87 BMI points, *s.d.*=1.36) between baseline and 3 months than those in BI (-.66, *s.d.*=1.15; *t*(156.08)=-7.72, *p*<.001, *d*=.095).,

(345 female) participants was included in this analysis. Participants in this sample had a mean baseline age of 56.62 years (*s.d.*=12.38), mean baseline BMI of 34.03kg/m^2 (*s.d.*=4.98) and a mean baseline PFS total score of 2.69 (*s.d.*=.91). This model was not significant (*p*=.73), suggesting there was no difference in the effect of either intervention on BMI change.

BMI changes between baseline and 12 months

Model 4 assessed the extent to which the effect of intervention (WW12 vs BI) on BMI change between baseline and 12 months was moderated by hedonic hunger. Data from 328 participants were included in this analysis. Sample characteristics are reported in section 3.3.3.1. The model approached significance: *R*^{2} =.02, *F* (3, 324) = 7.53, *p*=.08. Hedonic hunger was a marginally significant predictor of BMI change (*b*= .66, *SE* = .34, *p*=.05). Intervention type was a significant predictor of BMI change (*b*= 1.21, *SE* = .57, *p* =.03). The interaction between intervention and hedonic hunger approached significance (*b*= -.33, *SE* = .19, *p*=.09). Examination of the effect of intervention type on BMI change at different levels of the moderator revealed that at 1 standard deviation below mean hedonic hunger (low hedonic hunger) intervention type predicted BMI change (*b*=.61, *SE* = .26, *p*=.01). At the mean level of hedonic hunger (medium hedonic hunger) this prediction was marginally nonsignificant (*b* = .32, *SE* = .18, *p*=.07). At 1 standard deviation above the mean (high hedonic hunger) intervention type did not predict BMI change (*b*=

.03, *SE* = .24, *p*=.89). This suggests that the intervention was less effective for those with high hedonic hunger than low hedonic hunger. The effect of the intervention on weight loss can be seen by comparing BMI change in WW12 and BI: mean BMI change between 0 and 12 months was -2.02 (*s.d.*=2.71) BMI points for participants in WW12, and -1.41 (*s.d.*=2.89) BMI points for participants in BI arm of the trial; this difference was almost significant (*t*(326) =-1.75, *p*=.08, *d*=-.19). These results imply that WW12 was less effective in reducing BMI at 12 months for participants who had high hedonic hunger.

Model 5 assessed how the effect of intervention (WW52 vs BI) on BMI change between 0 and 12 months was moderated by hedonic hunger. Data from 346 participants were included in this analysis. Sample characteristics are reported in section 3.3.3.1. The overall model was highly significant: *F* (3, 342) = 6.70, *p* <.001, R^2 = .05. Hedonic hunger was not a significant predictor of BMI change (*p*>.05) but intervention type was (*b*=2.86, *SE* = 1.21, *p*=.01). The interaction between intervention type and hedonic hunger was not significant (*p*=.29). The effect of intervention type on BMI change at different levels of the moderator showed that for participants with low hedonic hunger, intervention type predicted BMI change (*b*=2.08, *SE* =.56, *p*<.001). This prediction was also significant in participants with medium hedonic hunger (*b*=1.68, *SE*=.38, *p*<.001) and high hedonic hunger (*b*=1.27, *SE*=.52, *p*=.01). These results suggest that the effect of intervention WW52 at each level of the moderator was relatively consistent.

Model 6 tested if the effect of intervention (WW52 vs WW12) on BMI change between baseline and 12 months was moderated by hedonic hunger. Data from 514 participants were included in this analysis. Sample characteristics are reported in section 3.3.3.1. The overall the model was significant: R^2 =.037, F(3, 510)=6.56, p<.001. Neither hedonic hunger nor intervention type[2] were significant predictors of BMI change (p's>.05) and the interaction between the two was nonsignificant (p>.05).

---

[2] These results are in contrast to those of the main WRAP trial results (Ahern et al, 2017), which showed greater BMI reduction in WW52 than WW12 between baseline and 12 months. The explanation for this is statistical. The 514 participants included in this analysis represent a subset of the data analysed by Ahern et al. Only data from participants who provided BMI and PFS scores through baseline, 3 and 12 months of the WRAP trial were included here, whereas Ahern et al. considered data from all participants enrolled in the trial in their analysis, thus reducing the statistical power of Model 6 compared to that of Ahern et al. Furthermore, Model 6 controlled for baseline hedonic hunger and the interaction between baseline hedonic hunger and intervention arm and, because they were a product of one another, these variables were collinear. When these variables are not controlled for results mirror those of Ahern et al in that participants in WW52 showed a significantly greater BMI reduction (-3.05 BMI points, s.d.=2.99) between baseline and 12 months than those in WW12 (-2.02, s.d.=2.71; t(512)=-4.09, p<.001, d=-3.60).,

3.4. Discussion

In this chapter, I have shown that the relationship between hedonic hunger and BMI during weight management is complex. Initially, I showed that greater baseline hedonic hunger was associated with higher baseline BMI (section 3.3.2). This finding is in line with results from Cappelleri et al. (2009), and also with suggestions by Thomas, Bechtell, Vestal, Johnson, Bessesen and Tregellas et al. (2013) that hedonic hunger is greater in individuals who are classed as obese-prone. The association between hedonic hunger and BMI in this study was positive but small, which is similar to that shown by Cappelleri et al., who studied participants engaged in weight management and the general population. Although Thomas et al. do not report the exact correlation between BMI and PFS total score, participants in their study who had higher hedonic hunger were classed as obese-prone and appeared to have a higher BMI. More data is needed to fully elucidate how strong (if any) the relationship between hedonic hunger and BMI is both within and beyond samples of participants undergoing weight management.

In this chapter, I also explored how different levels of hedonic hunger may moderate the effect of the intervention arm on BMI change during baseline to 3 months, and baseline to 12 months. This was explored through a series of moderation analyses (section 3.3.8). Results showed that intervention arm predicted BMI change, with WW12 and WW52 intervention arms producing greater BMI

reductions than BI. Results also showed no evidence for baseline hedonic hunger acting as a moderator of the effects of any intervention arm on BMI change between baseline and 3 month WRAP trial visits.

The second stage of the moderation analyses showed that Weight Watchers was less effective in people with higher hedonic hunger. Results of the moderation analyses referred to as Model 4 suggest that hedonic hunger moderated the effect of the intervention on BMI change between baseline and 12 months for WW12. When BMI change between baseline and 12 months of the WRAP trial from WW12 were compared to BI, the Weight Watchers intervention was less effective in people with high hedonic hunger than those with low hedonic hunger. This implies that people with high hedonic hunger who are referred to Weight Watchers for 12 weeks are likely to have a higher BMI at 12 months than people with low hedonic hunger. The implications of these findings for healthcare and weight loss endeavours are significant. In the UK, the NHS operates a 12-week referral system with Weight Watchers, where healthcare providers can refer overweight or obese patients to Weight Watchers for 12 weeks at no cost to the patient (Weight Watchers, n.d.). The financial cost of this is covered by the NHS, but the results of these analyses suggest that this referral approach may not be as effective long-term (at 12 months) when an individual entering weight management has high, as opposed to low, hedonic hunger. This indicates that high hedonic hunger poses a barrier to successful weight loss, and further suggests that identification of individuals with high hedonic hunger

prior to beginning weight management coupled with the provision of additional support for these individuals may improve their chance of having reduced BMI at 12 months. Interestingly, this pattern of results was not seen when comparing WW52 to BI (Model 5). This implies that hedonic hunger did not influence the effect of WW52 on BMI at 12 months, which may mean that the extended engagement with weight loss support offered by WW52 negates the vulnerability faced by participants with high hedonic hunger when they begin a short-term, more commonly used weight management intervention (WW12).

In this chapter, I also examined hedonic hunger over a two-year period, which, to my knowledge, represents one of the longest repeated assessments of hedonic hunger during weight management to date. Findings from the autoregressive cross-lagged model in section 3.3.5 showed that hedonic hunger at each time point predicted hedonic hunger at the subsequent time point. This shows that, although hedonic hunger decreased and remained reduced during the WRAP trial and, despite the weight changes experienced by participants, scores on the PFS predicted future scores over a 3, 9 and 12 month interval. Lowe and colleagues (2009) showed that the PFS had adequate test-retest reliability over a 4 month period, so this stability in PFS scores across 24 months adds supporting evidence for the reliability of the PFS as a psychometric measure of hedonic hunger. This also raises two interesting possibilities regarding the understanding of hedonic hunger as a concept itself. The stability in PFS scores shown in this study could be indicative

of the construct of hedonic hunger being relatively stable, suggesting that hedonic hunger is a trait-like characteristic. An alternative explanation could be that there is an underlying mechanism to hedonic hunger that remains somewhat constant.

A further aim of this study was to explore how hedonic hunger changed during and following a behavioural weight loss intervention. Across all interventions (WW12, WW52 and BI), hedonic hunger reduced from baseline to 3 months and remained suppressed at 12 and 24 month assessments. O'Neil et al. (2012) also examined weight loss following a 12 weeks Weight Watchers intervention, however they did not compare their findings to a control group so they could not ascertain if it was the Weight Watchers intervention or effect of weight loss itself or an effect of a conscious attempt to lose weight that may be behind the reported reduction in hedonic hunger. In this study, I addressed this limitation by comparing changes in hedonic hunger between participants engaged in Weight Watchers to participants in a control intervention (BI). My finding that the reduction in hedonic hunger was not specific to any intervention shows that the reduction in hedonic hunger was not a result of the Weight Watchers intervention. This means that, although behavioural weight management programmes such as Weight Watchers focus on topics related to identifying hedonic (as opposed to homeostatic) hunger (Weight Watchers, 2013), it may be something related to weight loss itself, not the Weight Watchers intervention, that reduces hedonic hunger. This suggests that hedonic hunger may be reduced by deliberate attempts to lose weight and the associated behavioural

and cognitive changes that are required to achieve this. This proposal can be somewhat supported by Schultes et al. (2010), who showed reduced hedonic hunger in post-operative bariatric surgery patients who had lost substantial amounts of weight, compared to pre-operative obese patients, suggesting a commonality between bariatric surgery patients and individuals undergoing behavioural weight loss. This commonality could be that weight loss produces changes in gut hormone signalling, which in turn reduces neural reward responses to palatable foods (Goldstone et al., 2016), which is then reflected as reductions in a measure of hedonic hunger. However, the auto regressive cross lagged model reported in this chapter did not show that BMI predicted future hedonic hunger at any time point, so this explanation cannot be supported. It is also noteworthy that this study addresses a limitation of the findings from Schultes et al. Schultes compared groups of patients to make inferences about changes in hedonic hunger following weight loss, so the unknown effect of potential between-group differences in their study cannot be discounted, whereas the findings of this study are based on data from the same participants tracked over time eliminating between group differences as a potential confounding factor.

By using an autoregressive cross lagged model of PFS total score and BMI at baseline, 3, 12 and 24 month WRAP trial visits, I have also shown that rather than baseline hedonic hunger predicting future BMI during the WRAP trial, hedonic hunger at 3 months predicted BMI at 12 months. The results of the autoregressive

cross-lagged model can be interpreted as a higher level of hedonic hunger score at 3 months being predictive of a higher BMI at 12 months. This suggests that change in PFS scores from pre-intervention measurements and after 12 weeks of weight management could be used to estimate an individual's BMI 12 months after weight loss endeavours began. Also, if it is possible to successfully reduce an individual's hedonic hunger during the first three months of dieting, they may have a lower BMI at 12 months than someone who maintains high hedonic hunger. More research on potential interventions that could achieve this would therefore be merited.

There was no effect of baseline or subsequent measures of hedonic hunger on BMI at 24 months, which suggests that the predictive properties of 3-month hedonic hunger scores do not persist to 24 months. In terms of the WRAP trial, this means that there was no evidence for hedonic hunger as measured at any time point as being predictive of BMI after 12 months of weight loss maintenance. These results could also indicate that the role hedonic hunger plays in weight management is relatively short-term, acting within the initial 12 months of weight management only rather than within longer-term weight loss maintenance. During the first 12 months of the WRAP trial, participants may have been adopting and establishing the lifestyle changes and habits necessary to successfully lose weight, and hedonic hunger is only predictive of BMI during this time. Once weight management goals are established and weight loss maintenance is underway, other factors may be more salient to successful weight management. Future studies

should explore this further by tracking hedonic hunger and other, related constructs, such as dietary restraint or self-regulation strategies, to see if different psychological constructs are more "active" and relevant at different times in the weight management journey.

An implication of the findings presented here is that when participants are classified as having high or low hedonic hunger, we may be separating them into subgroups that pursue their dieting goal through theoretically different means. Price, Higgs and Lee (2015) have suggested that hedonic hunger, as measured by the PFS, reflects a dual-approach to obesity, whereby bottom-up food reward sensitivity and top-down impulse control work in parallel to drive appetitive motivations and behaviour. Although only speculation, it may be that participants who had high hedonic hunger but still lost weight experienced more effective top-down impulse control to allow them to overcome elevated hedonic hunger, whereas those with reduced hedonic hunger may have experienced a dampening of bottom-up food reward sensitivity, which allowed them to pursue their dieting goal. If future research supports this, interventions could be tailored to increase impulse control and/or decrease food reward sensitivity alongside traditional behavioural intervention content, such as nutritional education and portion size control.

Limitations

There are some limitations to this study that should be noted. Firstly, the potential mechanism driving changes in hedonic hunger and its relationship with weight loss cannot be identified in this study. These data were observational in nature and underlying factors that drive changes in the relationship between hedonic hunger and BMI cannot be assumed. Future work should establish candidate characteristics that underlie hedonic hunger to see if individual variations in these subsequently drive the changes observed in this study.

A further limitation to this study is the relative homogeneity of the sample studied. The majority of participants self-identified as Caucasian. Ahern et al. (2017) have commented on this, stating that the proportions of participants who identified as each ethnic group is comparable to the ethnic composition of the UK (Office for National Statistics, 2016). This also applies to the current study. While representative of the current UK population, the limited diversity in the participants studied here means that the results should be generalised to other ethnic groups with caution. Comparison of the effects studied in this chapter with data from more diverse population groups is needed to support the generalizability of the findings in this chapter.

An additional limitation to this study relates to the limited statistical power to perform more complex analyses. The findings from the auto regressive cross lagged model reported in Section 3.3.3 collapsed across intervention group to

explore the relationship between hedonic hunger and BMI over time. This analysis was not repeated for each intervention arm of the WRAP trial because no evidence was found to suggest that intervention type affected hedonic hunger scores. However, had such an effect been found, this study would have been underpowered to perform this analysis separately for each intervention arm. The number of participants for whom full data was available decreased dramatically between baseline and 24 months, which is to be expected in a weight management trial of this length. The result of this was a drastically reduced amount of complete data in the BI arm of the trial, which would have been too small to power such complex analyses had an effect of intervention on hedonic hunger been observed.

Strengths

A key strength of this study is the length of time assessments covered. To my knowledge, this study represents the longest trial involving repeated assessments of the relationship between hedonic hunger and BMI in adults with overweight and obesity undergoing weight management. Previous studies have assessed hedonic hunger and weight in the same participants over limited periods of time, such as 12 weeks (O'Neil et al., 2012) or 15 weeks (Theim et al., 2013). The only study that conducted assessments over a comparable time period is by Cushing, Benoit, Peugh, Reiter-Purtill, Inge and Zeller (2014). These authors monitored hedonic hunger scores and BMI in 16 adolescents who underwent

bariatric surgery, however this study did not examine pre-intervention hedonic hunger scores so inferences about pre-post intervention hedonic hunger changes cannot be made. Compared to previous work, the strength of the study described in this chapter is the inclusion of pre- and post-intervention measures of hedonic hunger and measurements conducted over a prolonged period of assessment. Completion of the PFS at each WRAP trial visit allowed for an assessment of hedonic hunger prior to weight loss (baseline), during and immediately after a period of dieting (3/12 months), and following a period of weight loss maintenance (24 month assessment). Inferences made by this study can be used to estimate changes in hedonic hunger and BMI over extended time periods.

The use of Weight Watchers as the behavioural weight management intervention was another strength of this study. Weight Watchers is widely available throughout the UK, with "over 6000 (...) Weight Watcher meetings" taking place every week throughout the country (Weight Watchers, 2017). Referral to Weight Watchers is also offered in primary care in the UK, in accordance with guidelines to healthcare providers issued by NICE (National Institute of Health and Clinical Excellence, 2014). The BI arm of the WRAP trial also approximated the widely available weight loss advice offered in the UK by using guidance and a booklet offered by the British Heart Foundation (British Heart Foundation, 2005). By studying hedonic hunger and BMI in dieters engaged in interventions that are typically

available in the UK, I remain confident that the findings described in this chapter could be generalisable to the wider UK popualtion.

The use of an autoregressive cross-lagged model to examine relationships between hedonic hunger and BMI over 24 months is a key strength of this study. This analysis approach allows for a sophisticated examination of relationships and changes between variables over time, whilst controlling for covariates such as age and gender. Furthermore, results at each time point of the model account for variance associated with the previous time point, so I am confident that the results of the model are reflective of the pattern of relationships between the data.

The WRAP trial was a Randomised Control Trial (RCT), and this provides another key strength of this study. RCT's are regarded as a crucial element and the "gold standard" of clinical research (Stang, 2011) as the random allocation of participants to interventions ensures that participant groups are comparable. This also ensured that allocation of participants with differing hedonic hunger scores and demographic characteristics that could have influenced weight loss was comparable across intervention arms, so I can be confident that the effects described in this chapter are not due to bias in assigning participants to interventions.

A final strength of the current study was the proportion of male participants included in the sample. Ahern et al. (2017) have previously reported this as a strength of the overall WRAP trial, but this also applies to the investigations

described in this chapter. In a previous study of weight loss from referral to behavioural weight management, Ahern et al. (2011) did not recruit a large enough number of male participants to be representative of the UK population. Although the proportion of male participants in the current study (390 male : 840 female) was below that in the UK population (Office for National Statistics, 2011), the proportion of males participants included in this chapter is still higher than in Ahern et al. (2011).

Summary

This chapter showed that WW12 was less effective at 12 months in people with high baseline hedonic hunger than low hedonic hunger, that hedonic hunger reduced with weight loss between baseline and 3 months, and that higher hedonic hunger at 3 months predicts a higher BMI at 12 months. While these results provide an understanding of the relationships between hedonic hunger and BMI during the WRAP trial, the mechanisms driving or manifestations of these relationships are still unknown.

One potential manifestation of the relationship between hedonic hunger and BMI during weight loss may be in the way hedonic hunger interacts with the obesogenic environment (an environment conducive to overweight and obesity [Swinburn, Egger, & Raza, 1999; Swinburn et al., 2011]). Lowe and Butryn (2007) suggested that hedonic hunger may be triggered by environmental food cues that

signify the presence and availability of palatable foods. The abundance of such food cues is characteristic of the obesogenic environment. Considered alongside Thomas and colleagues' (Thomas et al. 2011) finding that those with a higher BMI had a greater probability of overeating in the presence of palatable foods, one potential mechanism driving hedonic hunger may be an increased sensitivity to food cues, manifested as heightened food cue reactivity. In Chapter Four, I assessed whether hedonic hunger is associated with heightened reactivity to food cues, whether this changes during a behavioural weight loss programme, and how such a relationship may be related to weight loss.

Chapter 4 - The relationship between hedonic hunger and attentional bias to food cues during weight loss

4.1. Introduction

Initial descriptions of hedonic hunger suggested that it may be triggered by food cues, which signal the presence or availability of food (Lowe & Butryn, 2007). As described in Chapter 1, reactivity to food cues, in the form of attentional bias towards food, has been found in sated individuals with overweight (Castellanos et al, 2009) and is associated with chocolate craving (Kemps & Tiggemann, 2009), external eating (Brignell et al, 2009), food craving (Werthmann et al, 2011; Brockmeyer et al, 2015) and obesity itself (Hendrikse et al, 2015). A number of recent propositions support the hypothesis that individuals with higher levels of hedonic hunger may be more reactive to food cues. However, to date, limited work has assessed the relationship between hedonic hunger and attentional bias towards food.

Shank (2013) explored the relationship between attentional bias (AB; as a measure of food cue reactivity) to palatable foods and hedonic hunger in normal weight, non-dieting females following a fasting manipulation. Results showed no association between attentional bias and hedonic hunger, although it should be noted that this study used a reaction time (RT) index of attentional bias, whereas Christiansen, Mansfield, Duckworth, Field and Jones (2015) propose that eye movement recordings provide a more reliable method of assessing attentional bias. Other authors have suggested that hedonic hunger may have been triggered by

food cues used in an attentional bias task. Nijs, Muris, Euser and Franken, (2010) reported that both participants with overweight or obesity, and participants with normal weight, displayed attentional bias towards food cues, but the magnitude of this was greater in participants with overweight or obesity, especially when in a hungry state after a 17 hour fast. The authors used a milkshake to induce satiety in participants and speculated that the limited palatability of the milkshake may have quelled physiological hunger but produced hedonic hunger in their participants. That is, the caloric content of the milkshake fulfilled participants' energy needs, but the limited palatability left them with a hedonic need that was activated by the food cues in the experimental task. However, the authors did not explicitly measure hedonic hunger so any association between hedonic hunger and attentional bias is speculative. Hendrikse and colleagues (2015), in a recent review of attentional bias to food cues and obesity, commented that consummatory behaviours appear to be influenced by a combination of attentional bias to food cues and self-control deficiencies when faced with palatable foods. The urges for palatable foods referred to here could arguably be seen as a manifestation of hedonic hunger, however this was not examined. Could the urges for palatable foods actually be a manifestation of hedonic hunger? In this chapter I directly examined whether self-reported hedonic hunger is associated with attentional bias towards food cues in adults with overweight or obesity, using both reaction time biases and eye tracking data.

Given the omnipresence of food cues in most Western environments, a heightened attentional bias to food cues may be especially challenging during dieting, presenting individuals who have heightened hedonic hunger with an

additional barrier to weight loss success (Lowe & Butryn, 2007). When attempting to lose weight, such individuals may be already battling against a heightened drive for tempting foods because they are more sensitive to the rewarding properties of palatable foods that they are denying themselves as part of their dietary plan. When combined with an environment conducive to developing overweight (Section 1.3) where cues to obtain and eat food may derail dieting attempts, individuals with an unfortunate combination of heightened hedonic hunger and heightened food cue reactivity may need to expend additional effort to maintain successful dieting behaviours. Identifying individuals who have this enhanced susceptibility at the start of a weight management programme would mean they could be offered additional support to reduce their reactivity to food cues and resist foods not conducive to their weight loss goals.

There is a growing body of evidence to support an association between change in hedonic hunger, as measured by the Power of Food Scale (PFS), and weight loss. Chapter 3 demonstrated that reductions in hedonic hunger are seen with weight loss during a behavioural weight management programme. This finding is supported by other studies that have shown that hedonic hunger is lower in post-operative gastric bypass patients than obese control patients (Schultes, Ernst, Wilms, Thurnheer, & Hallschmid, 2010; Ullrich, Ernst, Wilms, Thumeer, Hallschmid & Schultes, 2013), although longitudinal, compared to between group, assessment of hedonic hunger in bariatric surgery patients is lacking (Section 1.52). Chapter 3 also demonstrated that reductions in hedonic hunger are *predictive* of weight loss during behavioural weight management, and complimentary support for this comes from

findings that show reduced hedonic hunger in obese adolescents following bariatric surgery and subsequent weight loss (Cushing et al., 2014b). Furthermore, a recent review highlighted that hedonic drive to consume palatable foods was reduced in obese patients following bariatric surgery (Hansen, Jakobsen, Nielsen, Sjödin, Le Roux & Schmidt, 2016).

Evidence for reduced hedonic hunger following weight loss is not limited to bariatric surgery research. O'Neil, Theim, Boeka, Johnson and Miller-Kovach (2012) demonstrated that reductions in hedonic hunger over the course of a 12-week behavioural weight loss intervention (Weight Watchers) was associated with increased weight control behaviour usage and weight loss, particularly in participants who displayed elevated hedonic hunger prior to beginning of the intervention. Theim, Brown, Juarascio, Malcolm and O'Neil (2013) also showed a similar pattern of results. Theim and colleagues (2013) found that weight control behaviour usage increased and hedonic hunger decreased over the course of a 15-week partial meal replacement weight loss intervention, and that these changes were in turn associated with weight loss. Taken together, the surgical and behavioural data on hedonic hunger and weight loss provide strong evidence for the relationship between reduced hedonic hunger and weight loss, however, relatively little research has examined the mechanisms driving this relationship. To date, no studies have examined whether changes in hedonic hunger and weight loss are associated with changes in attentional bias to food cues. The study described in this chapter attempted to address this gap in the literature.

In this study, I investigated the relationship between hedonic hunger and food cue reactivity in dieters by measuring hedonic hunger and attentional bias to food cues in non-fasted adults before and after 12 weeks of behavioural weight management. I aimed to provide the first evidence for the association between hedonic hunger and food cue reactivity in overweight and obese adults who want to lose weight, and to examine changes in these parameters following participation in a behavioural weight loss programme. Therefore the questions addressed by this study were:

1.   Is hedonic hunger (PFS score) associated with attentional bias to food cues (reaction time and gaze duration for low and high calorie foods) in adults with overweight and obesity who are motivated to lose weight?

2.   Does attentional bias to food cues (reaction time and gaze duration for low and high calorie foods) change during participation in a behavioural weight loss programme (Weight Watchers)?

3.   Are changes in hedonic hunger (PFS Score) associated with changes in attentional bias to food cues (reaction time and gaze duration for low and high calorie foods)?

4.   Is the association between hedonic hunger and attentional bias different in those who have high hedonic hunger (greater PFS score), relative to those with low hedonic hunger (lower PFS score)?

5.   Are changes in attentional bias to food cues during a weight management programme different for high and low hedonic hunger groups?

6.   Are changes in attentional bias to food cues associated with weight loss?

7.   Are changes in hedonic hunger associated with weight loss?

4.2. Method

4.2.1. Participants

Participants comprised adults with overweight or obesity who were undertaking an open-group behavioural weight loss programme (the Weight Watchers programme, described in Section 2.2). It was intended that participants would be recruited solely from participants enrolled in the WRAP trial at the Liverpool site. Recruitment of WRAP trial participants did not yield the required number of participants so the study recruitment criteria were extended to include community-dwelling members of the Liverpool and Wirral area. The two methods of recruitment are described below.

One hundred potential participants were screened for eligibility by telephone, of which 73 were deemed eligible for the study and invited to attend a baseline assessment (T1). Eleven eligible participants did not attend the T1 appointment. Sixty-two participants enrolled in the study, of which 57 participants completed all study procedures. The final study sample consisted of 57 participants

(51 women, 6 men). Seventeen participants were taking part in the WRAP trial; 40 were community-dwelling volunteers. Participant characteristics at baseline are displayed in Table 4.1. All participants received a £30 honorarium plus travel expenses for their time and inconvenience.

4.2.2. Participant Recruitment

WRAP participants: WRAP trial participants who were randomised to either of the behavioural programme arms and who had consented to being contacted about other research studies were offered information about the current study at their baseline WRAP trial appointment, and asked if the researcher could telephone them to discuss the study. The study was advertised as an investigation of reactions to information about food in people who want to lose weight. If the participant agreed, the researcher telephoned them at least 24 hours after the baseline appointment to ensure that the participant had adequate time to read and consider the information. Participants were screened for eligibility by telephone. If they were deemed eligible for the study, an appointment for the T1 visit was scheduled prior to the participant's first Weight Watchers meeting.

Community participants: Members of the staff and student population of the University of Liverpool and the wider Merseyside and Wirral communities were recruited by online advertisements, posters and by opportunity, word of mouth and snowball sampling methods. As with the WRAP participants, the study was described as an investigation of reactions to information about food in people who want to lose weight. Study advertisements also stated that participants would be

given vouchers to attend Weight Watchers for 12 weeks and access to the Weight

Watchers e-Source at no cost to them.

Table 4.1 Participant baseline characteristics

	Mean	*Standard deviation*
Age (years)	44.98	9.77
BMI (kg/m^2)	34.012	4.34
Weight (kg)	92.79	13.41
PFS Total Score	3.06	.96

4.3. Design

This study followed a repeated measures design, whereby all participants completed measures of attentional bias (reaction time and gaze duration) and hedonic hunger (PFS total score) in a non-fasted state at baseline (T1) and at 12 weeks (T2).

For the exploratory analyses described in Section 4.3.5 a mixed design was adopted: participants were split into high and low hedonic hunger groups (by median split of PFS score) and compared across T1 and T2. T1 measures reflect pre-intervention levels of hedonic hunger, weight, BMI and AB, whereas T2 measures reflect post-intervention levels of these variables.

4.3.1. Measures and Procedure

The measures used in this study are described in detail in Chapter 2 and include the PFS (as a measure of hedonic hunger), a visual probe task with concurrent eye movement recording, height and body weight. Participants completed all measures before starting the behavioural weight management programme (T1) and again 12 weeks later (T2). Participants were non-fasted and no specific instructions were given to participants regarding restriction of food prior to arriving at the laboratory. Previous work has shown no effect of satiety on laboratory assessment of attentional bias in participants with overweight (Doolan, Breslin, Hanna, Murphy, & Gallagher, 2014), and no effect of fasting status on PFS scores in the WRAP trial was found in Chapter 2 (Section 2.3.9).

Testing took place in the Eye Tracking Laboratory at the University of Liverpool (UK) between the hours of 8:30am and 5pm. Testing sessions were not constrained to a set time of day (e.g. afternoon) because of limitations to participant and laboratory availability. Wherever possible, each participant's T2 appointment was scheduled at the same time of day as their T1 appointment. The mean difference in number of minutes between scheduled T1 and T2 times was 106.02 minutes (*s.d* = 130.89). A schematic of the study procedure is shown in Figure 4.1.

```
┌─────────────────────────────────────────────────────────┐
│                           T1                            │
│                     Hedonic Hunger                      │
│       Visual probe task with eye movement recording     │
│                     Height and weight                   │
└─────────────────────────────────────────────────────────┘
                            │
                            ▼
┌─────────────────────────────────────────────────────────┐
│                12 Weeks Weight Watchers                 │
└─────────────────────────────────────────────────────────┘
                            │
                            ▼
┌─────────────────────────────────────────────────────────┐
│                           T2                            │
│                     Hedonic Hunger                      │
│       Visual probe task with eye movement recording     │
│                         Weight                          │
└─────────────────────────────────────────────────────────┘
```
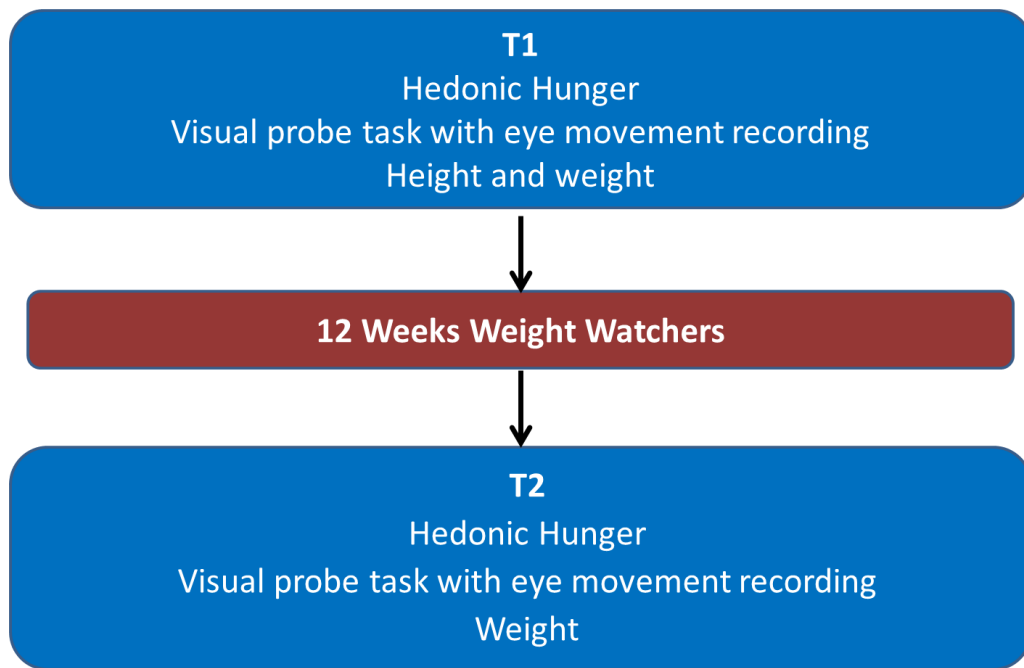
Figure 4.1 Schematic representation of the study procedure.

During the 12 weeks of behavioural weight management, participants were provided with access to 12 Weight Watchers meetings and the Weight Watchers e-Source (see Section 2.3.1 for details). Participants followed the Weight Watchers plan independently within a community setting.

4.3.2. Attentional Bias Scores

Stimuli in the visual probe task were colour images of high calorie (HC) and low calorie (LC) foods and neutral household items. Food images were presented alongside neutral images that were matched for colour and image complexity. An example of the stimulus display is presented in Figure 4.2. The distinction of high and low calorie food image stimuli allows for more detailed assessment of AB. Six indexes of AB were measured during the visual probe task: three indirect (Reaction time-RT-bias) and three direct (gaze dwell-GD-bias).

These indexes were:

- RT AB to food cues – derived from RTs to probes that replaced food images (HC and LC collapsed) vs RTs from probes that replaced neutral images considered all food stimuli.

- RT AB to high calorie foods – derived from RTs to probes that replaced HC images vs RTs from probes that replaced neutral images.

- RT AB to low calorie foods derived from RTs to probes that replaced LC images vs RTs from probes that replaced neutral images

- GD AB to all foods – derived from the difference in dwell time from fixations on food stimuli vs neutral stimuli.

- GD AB to high calorie foods – derived from the difference in dwell time from fixations on high calorie food stimuli vs neutral stimuli.

- GD AB to low calorie foods – derived from the difference in dwell time from fixations on low calorie food stimuli vs neutral stimuli.

Figure 4.2 Example of a stimulus display in the visual probe task. The left image (French fries) represents a high calorie food. The right image (broom head) represents a neutral, household item.

4.4. Results

4.4.1. Data preparation

Data were assessed for adhering to assumptions of parametric analyses using the Kolmogorov-Smirnov test. All analyses were conducted using IBM SPSS version 22 for Windows (IBM SPSS Inc., Chicago, USA). The threshold for significance was $p < .05$ except for where the threshold was adjusted to $p < .01$ to correct for multiple comparisons. This option was selected in favour of Bonferroni adjustments because the number of analyses carried out were limited to planned comparisons (sections 4.3.1-4.3.3) or were of an exploratory, post-hoc nature (sections 4.3.5-4.3.7) and were already subject to a conservative analysis plan aimed to reduce Type 1 error (section 4.3.5). This analysis approach follows suggestions by Armstrong (2014).

Prior to analysis, RT data were prepared for analysis using techniques common in the AB literature (e.g. Christiansen et al., 2015; Lattimore & Mead, 2015). The missing data threshold was decided at 10%, whereby any participant losing ≥ 10% of their data from trimming purposes would be removed from analyses. No participants were excluded based on this criterion.

Trials on which RTs were <200ms or >2000ms and errors were removed. RTs faster than 200ms were deemed anticipatory and RTs slower than 2000ms were considered to be delayed. RT bias was calculated by subtracting mean RT on trials where the visual probe replaced the food image from mean RT from trials where the

visual probe replaced the neutral image. This process was repeated for HC only and LC only trials to generate the HC bias and LC bias scores. Positive scores indicate AB.

GD times were extracted from eye movement recordings. Eye movements were classed as a fixation if they remained stable for at least 100ms and within one degree of visual angle. These parameters are accordance with Christiansen et al. (2015). GD bias was calculated by subtracting dwell time on neutral images from dwell time on food (HC/LC collapsed) images. This process was repeated for HC only and LC only images to generate the HC-bias and LC-bias scores. Positive scores indicate GD AB. Forty-one participants provided eye movement data. Reasons for lack of eye movement data in sixteen participants were: equipment failure, poor/unsuccessful calibration of eye tracker or the participant wore spectacles that prevented eye movement recording. PFS total score was calculated in accordance with author guidelines described in   Section 2.4.1.

4.4.2. Changes in weight, BMI and hedonic hunger

Changes in weight, BMI and hedonic hunger between T1 and T2 are shown in Table 4.2 On average, participants lost weight over the course of the study. Mean weight change between T1 and T2 was -3.88kg ($s.d$ = 4.01kg). This equates to a significant decrease in BMI between T1 and T2 of 1.37kg/m^2 ($t(56)$ = - 7.59, p <. 001, d=.032). On average, participants' hedonic hunger also decreased during this time. Mean PFS total score was significantly lower at T2 than at T1 ($t(56)$ = - 5.91, p <.001, d = .49). These findings are consistent with findings from Chapter 3, whereby there

was a significant reduction in hedonic hunger following 12 weeks of weight management.

Table 4.2 Mean (s.d.) changes in weight (kg), BMI and hedonic hunger (PFS total score). Negative numbers indicate a decrease.

	T1	T2	Change between T1 and T2	*p*
Weight (kg)	92.79 (13.41)	88.91 (12.12)	-3.88 (4.01)	<.001
BMI (kg/m^2)	34.01 (4.34)	32.64 (4.27)	-1.37 (1.37)	<.001
PFS Total Score	3.06 (.96)	2.59 (.91)	-.46 (.59)	<.001

4.4.3. Is hedonic hunger associated with attentional bias to food cues in adults with overweight and obesity who are motivated to lose weight?

A significant positive correlation between baseline PFS total score and baseline RT AB to HC food cues was observed (r = .28, p = .035), however, after correction for multiple testing was applied, this value was no longer significant (p > .01). The correlation between PFS total scores and GD AB to HC foods did not reach significance but indicated a similar pattern (r = .27, p = .096). Correlations between baseline PFS total score and other indexes of attentional bias were not significant (p's > .1). Based on analyses using corrected p values, these results suggest that there is no association between baseline hedonic hunger and attentional bias in adults with overweight and obesity who are motivated to lose weight prior to active weight management.

4.4.4. Does attentional bias to food cues change during participation in a behavioural weight loss programme?

To assess whether attentional bias to food cues changes during a behavioural weight management programme, bias scores from T1 were compared to bias scores for T2 using a paired samples t-test. This was done for each of the six indexes of attentional bias calculated from the data (see Table 4.2). Results indicate that gaze dwell time bias to low calorie foods was significantly increased between T1 and T2 (t(38) = -2.111, p = .042, d = -.68), however after correction for multiple comparisons was applied (adjusted p = .01) this difference was no longer significant. All other comparisons were not significant. This suggests that attentional bias to

food cues does not change during participation in a behavioural weight loss

programme.

Table 4.3 Mean (standard deviation) of each index of attentional bias at T1 and T2 and results of tests for significant differences between bias scores. All differences non-significant at the adjusted level (p = .01).

AB index

	T1	T2	t	df	p
RT bias to food cues	2.06 (22.87)	6.86 (24.15)	-1.11	56	.27
RT bias to high calorie food cues	-.99 (36.30)	1.81 (31.12)	-0.38	56	.70
RT bias to low calorie food cues	4.96 (32.72)	11.74 (30.91)	-1.17	56	.24
Gaze dwell bias to food cues	.00 (.12)	.03 (.11)	-1.78	37	.08
Gaze dwell bias to high calorie food cues	.00 (.18)	.02 (.14)	-0.70	36	.49
Gaze dwell bias to low calorie food cues	.00 (.09)	.04 (.11)	-2.11	37	.04

Note. RT=reaction time

4.4.5. Are changes in hedonic hunger associated with changes in attentional bias to food cues?

To investigate if there was a relationship between changes in hedonic hunger and attentional bias, change scores for PFS and indexes of attentional bias were calculated by subtracting T1 scores from T2 scores. Change scores are displayed in Table 4.4. A series of Pearson's correlations were conducted between PFS change score and each of the attentional bias change scores listed in Table 4.3. Significant positive correlations were found between changes to PFS total scores and change in gaze dwell time bias to food cues ($r = .327$, $p = .045$) however, after correction for multiple comparisons was applied (adjusted $p = .01$), this association was no longer significant. Results also showed a marginally significant association between change in hedonic hunger and change in gaze dwell time bias to high calorie food cues ($r = .416$, $p = .01$). This demonstrates that reduction in hedonic hunger was associated with reduction in gaze dwell bias to high calorie foods. Correlations between change to PFS total score and all other indices of change in attentional bias were not significant (p's > .05).

Table 4.4 Mean and standard deviation change scores for PFS total and attentional bias scores. Change score represents differences between T1 and T2. Negative (-) figures represent a decrease.

	Mean	*Standard deviation*
PFS Change	-.46	.59
RT bias to food cues change score (ms)	4.80	32.79
RT bias to high calorie food cues change score (ms)	2.80	54.98
RT bias to low calorie food cues change score (ms)	6.78	43.70
Gaze dwell bias to food cues change score (ms)	.003	.10
Gaze dwell bias to high calorie food cues (ms)change score	.02	. 16
Gaze dwell bias to low calorie food cues change score (ms)	.04	.11

Note. RT=reaction time; ms = millisecond

4.4.6. Interim summary

Results thus far suggest that, in this sample, hedonic hunger decreases over 12 weeks of engagement with behavioural weight management, but change in hedonic hunger is only marginally associated with changes in AB to high calorie foods. These results come from analysis of the sample as a whole; however, inspection of the variability in participants' baseline PFS total scores revealed that scores ranged from 1.29 to 4.87 within this sample of participants. For reference, the range of possible PFS total scores is 1 to 5 (Lowe et al., 2009). The large range of PFS scores within this sample suggests that there may be considerable differences between participants at opposing ends of this range. Given my previous findings that PFS total score moderates the effect of intervention on weight change (Chapter 3) in different ways depending on how much above or below the sample mean PFS scores fall, the effect of this variability in PFS scores on relationships with AB in this sample of participants suggests a need for additional exploratory analysis. It may be that examining the sample as a whole is not the most sensitive or appropriate method to adopt as within group differences may be masked. It may be possible that participants with higher hedonic hunger display a different relationship between PFS scores and AB those participants with lower hedonic hunger, and by examining hedonic hunger-AB relationships in a mixed sample, more subtle differences in such hedonic hunger sub-groups were overlooked.

To explore sub-sample differences in the relationship between hedonic hunger and attentional bias, participants were separated into high and low hedonic

hunger groups by median split (*median* = 3.07). Participants in the high hedonic hunger group (*n* = 28) had significantly higher T1 PFS total scores than those in the low hedonic hunger group (*n* = 29; *t*(55) = 10.36, *p* <.001, *d* = 2.79). Participants with high hedonic hunger also experienced a greater change in PFS scores than those with low hedonic hunger (*t*(38.41) = 3.31, *p* = .002, *d* = .08 ; equal variances not assumed; see table 4.5). These differences suggest there may be between-group differences within this sample and therefore justifies investigation into group differences in attentional bias.

Table 4.5 Mean (±standard deviation) d PFS total scores and change scores for high and low hedonic hunger groups. Negative values indicate a decrease.

Hedonic hunger group	T1 PFS Score	T2 PFS Score	*T1-T2 change*
Low hedonic hunger group	2.29 (±.56)	2.07 (±.56)	-0.22 (±.33)
High hedonic hunger group	3.84 (±.57)	3.13 (±.90)	-0.70 (±.69)

4.4.7. Is the association between hedonic hunger and attentional bias different in those who have high hedonic hunger, relative to those with low hedonic hunger?

Group differences in the relationship between changes in hedonic hunger and changes in attentional bias were first explored by repeating the correlational analysis described in Section 4.4.3 for high and low hedonic hunger groups. Data were classed as high or low hedonic hunger based on a median split of T1 PFS total scores. To reduce the risk of Type 1 error, only the significant and trend relationships (prior to adjustment for multiple comparisons) identified in sections 4.3.2 – 4.3.5 were reassessed. An adjusted *p* value of *p*= .01 was applied for these analyses.

Analysis identified a correlation between PFS score change and change to gaze dwell bias to food (r = .536, p = .015) for participants with high hedonic hunger, although this was no longer significant after adjusting for multiple comparisons. A significant correlation was found between change in hedonic hunger and change to gaze dwell bias to high calorie foods (r = .581, p = .007) for participants in the high hedonic hunger group. A marginally significant association between change in hedonic hunger and change in RT bias to low calorie food cues (r = .469, p = .012), again for the high hedonic hunger group only. No significant correlations between these scores were found in the low hedonic hunger group. This suggests it was change scores from participants in the high hedonic hunger group that were driving the results identified in Section 4.4.3. The above results imply that there may be dissociation between high and low hedonic hunger groups and the

relationship between PFS total scores and attentional bias. To explore this further data were submitted to a series of mixed ANOVAs. Change scores for indexes of attentional bias are shown in Table 4.5.

Table 4.6 Mean (s.d.) AB and AB change scores for high and low hedonic hunger groups.

AB index (ms)	Low hedonic hunger group			High hedonic hunger group		
	T1 score(*s.d.*)	T2 score (*s.d.*)	T1-T2 change (*s.d.*)	T1 score (*s.d.*)	T2 score (*s.d.*)	T1-T2 change (*s.d.*)
RT AB to food cues	-.1.21 (21.58)	12.04 (20.71)	13.24 (35.46)	5.43 (24.07)	1.15 (26.58)	-3.94 (27.76)
RT AB to high calorie food cues	-11.51 (34.31)	10.57 (25.24)	22.08 (49.96)	9.91 (35.65)	-7.26 (34.35)	-17.18 (53.55)
RT AB to low calorie food cues	9.01 (28.86)	13.39 (27.75)	4.37 (40.51)	.75 (36.35)	10.03 (34.31)	9.28 (47.40)
GD AB to food cues	-.02 (.10)	.02 (.08)	.04 (.09)	.03 (.13)	.04 (.13)	.01 (.10)
GD AB to high calorie food cues	-.55 (.14)	.02 (.11)	.07 (.15)	.06 (.19)	.03 (.17)	-.03 (.15)
GD AB to low calorie food cues	.01 (.10)	.02 (.09)	.01 (.10)	.00 (.08)	.05 (.13)	.05 (.12)

4.4.8. Are changes in attentional bias to food cues during a weight management programme different for high and low hedonic hunger groups

Group differences in changes in RT AB to all foods over time.

Data were analysed using a 2 (hedonic hunger between subjects group: high, low) x 2 (time: T1 RT bias to food cues, T2 RT AB to food cues) mixed ANOVA. No main effects of time or group were observed (p's > .01).

Group differences in changes in RT AB to high calorie food cues over time.

Data were analysed using a 2 (hedonic hunger between subjects group: high, low) x 2 (time: T1 RT AB to high calorie food cues, T2 RT AB to high calorie food cues) mixed ANOVA. No main effects of time or group were observed (p's > .01). A significant group x time interaction was observed ($F(1,55) = 8.202$, $p = .006$, $\eta_p^2 = .130$). Analysis of this interaction revealed no significant differences between high and low hedonic hunger groups in changes to AB to high calorie foods.

Group differences in RT attentional bias to low calorie food cues over time

Data were analysed using a 2 (hedonic hunger between subjects group: high, low) x 2 (time: T1 RT bias to low calorie food cues, T2 RT bias to low calorie food cues) mixed ANOVA. No main effect of time, group or group x time interaction were

observed in the analysis of group differences in RT bias to low calorie food cues over time (p's > .01).

Group differences in gaze dwell bias to food cues over time

Data were analysed using a 2 (hedonic hunger between subjects group: high, low) x 2 (time: T1 Gaze dwell bias to food cues, T2 Gaze dwell bias to food cues) mixed ANOVA. No main effects of time or group or a time x group interaction were observed (p's > .01).

Group differences in gaze dwell bias to high calorie food cues over time

Data were analysed using a 2 (hedonic hunger between subjects group: high, low) x 2 (time: T1 Gaze dwell bias to high calorie food cues, T2 Gaze dwell bias to high calorie food cues) mixed ANOVA. No main effects of time or group, or a group x time interaction were observed (p's > .01).

Group differences in gaze dwell bias to low calorie food cues over time

Data were submitted to a 2 (hedonic hunger group: high, low) x 2 (time: T1 gaze dwell bias to low calorie food cues, T2 gaze dwell bias to low calorie food cues) mixed ANOVA. Results showed no significant main effect of time, group, or group x time interaction (p's > .01).

4.4.9. Are changes in attentional bias to food cues associated with weight loss?

A series of Pearson correlations between weight loss (kg) and change score for each index of attentional bias were conducted. No significant correlations were observed (all p's >. 01). No associations between changes in attentional bias to food cues and weight loss were present in these data.

4.4.10. Are changes in hedonic hunger associated with weight loss?

A Pearson correlation between change in PFS total score and weight loss (kg) revealed no significant association between PFS score change and weight loss (p > .01).

4.5. Discussion

In this chapter I showed that there is not a clear cross-sectional relationship between hedonic hunger and attentional bias to food cues in adults with overweight and obesity who are about to begin a weight management intervention. Baseline PFS scores were not associated with baseline attentional bias to food images depicting low-calorie foods, high-calorie foods, or a combination of these. This pattern of results is in accordance with Shank (2013), who did not observe an association between hedonic hunger and attentional bias to food cues in a female sample of 61 undergraduate students of normal weight. The current study employed a similar attentional bias task to Shank (visual probe task) with a similar stimulus set of food and neutral, household image stimuli. The similarity in findings between the current study and Shank's, achieved using a similar sample size and assessment measure for AB, suggests that either cross sectional relationships between hedonic hunger and AB do not exist, or, if they do, a visual probe task is not sensitive enough to measure this. Recent discussion of the use of RT versus GD measures of AB has suggested that the reliability of the visual probes task is improved by use of eye movement recordings to measure GD AB (Christiansen et al., 2015). The current study adhered to this so I can be confident that the measures of AB in this study are more reliable than Shank's report of RT based AB. However, a sizeable proportion of GD AB scores are missing in the current study due to equipment failure issues, and

the study may be underpowered to detect significant effects. Future studies may wish to employ alternative methods of assessing AB, such as electrophysiological brain activity recording. Nijs et al. (2010) have previously shown event-related potential (ERP) findings indicate AB that a visual probe task did not reveal. Future work should look to confirm this by employing more than one method of assessing AB.

In the current study, PFS scores decreased, on average, over the 12 weeks of weight management, as is consistent with the findings of Chapter 3 and other investigations of hedonic hunger during weight loss (O'Neil, Theim, Boeka, Johnson, & Miller-Kovach, 2012; Theim, Brown, Juarascio, Malcolm, & O'Neil, 2013; Ullrich, Ernst, Wilms, Thurnheer, & Schultes, 2013). Results of the current study showed that, on average, attentional bias did not significantly change during a behavioural weight management programme. However, analysis suggests that there may be an association between change in hedonic hunger and AB and that this relationship may be moderated by baseline hedonic hunger. A statistically significant correlation between changes in hedonic hunger and change in GD AB to high calorie foods was observed in the sample as a whole, with reductions in hedonic hunger being associated with reductions in GD AB for high calorie foods. Exploratory analyses were conducted to investigate this finding.

Exploratory analyses showed that the relationship between changes in hedonic hunger and changes in GD AB was strongest in those with high hedonic hunger at baseline. In participants with high hedonic hunger, changes in hedonic hunger were correlated with changes in gaze dwell bias to HC food cues, meaning that as hedonic hunger reduced, so did the tendency for participants to focus on HC food images for longer than neutral images.

The stronger relationship between change in GD AB and change in hedonic hunger in the high hedonic hunger group may be due to the fact that this group had larger and greater variability in changes in hedonic hunger, whereas the low hedonic hunger group had less potential to reduce PFS scores as these were already low at baseline. The high hedonic hunger group may have also shown reductions in AB to HC foods because of lifestyle changes implemented during the course of weight loss. During this time it could be that participants with high hedonic hunger had successfully managed to reduce their tendency to fixate on the HC foods because the HC images used in this study represent foods that would not be compatible with their dieting goals. It might be that seeing the HC foods at T2 activated a dieting goal, as after 12 weeks of weight management successful restriction of these foods may have become established. This explanation is consistent with discussion of how palatable food images can prime hedonic eating, but this may be offset by cues that activate the dieting goal to inhibit this and promote dieting success (Papies, 2012). Following this discussion, this would

suggest that during the course of their successful weight loss, participants with high hedonic hunger may have also had an established dieting goal which, when activated by the food stimuli in the visual probe task, served to influence the cues to which they allocated their attention.

Change in hedonic hunger was not related to weight loss in this study. This is in contrast to results by O'Neil et al. (2012), who showed an association between weight loss and reductions in hedonic hunger in participants who also increased their weight control behaviour usage. However, the sample size was larger in O'Neil and colleague's experiment than in the current study (N = 111), so the current study may have been underpowered to detect statistically significant effects. Furthermore, weight control behaviour usage was not examined in this study, so it could be that an effect of hedonic hunger reduction on weight loss would emerge if it had been possible to identify participants who adopted increased weight control behaviours. Alternatively, this finding is in line with findings from Chapter 3 which showed that the association between change in hedonic hunger and BMI was only apparent between hedonic hunger at 3 months and BMI at 12 months. In Chapter 3, an autoregressive cross-lagged model showed that higher hedonic at 3 months was predictive of higher BMI at 12 months, so, taken with the lack of association between hedonic hunger change and weight change in this study, these findings suggest that the role of hedonic hunger may be more evident long-term, or beyond the initial weight loss stages that were assessed in this study.

Limitations

There are several limitations to this study. One limitation relates to the stimuli used in the visual probe task. Although stimuli were selected and categorised as high and low calorie foods based on descriptions of stimuli used in other studies, the current study did not assess participants' liking of the foods or the stimuli. The range of foods selected may not have been reflective of foods that appealed to the participants or, perhaps, foods that they classed as high and low calorie. Following Christiansen et al.'s (2015) suggestion, personalised stimuli, selected to be salient to the individual participants, may allow for a more valid and reliable assessment of attentional bias.

Although all participants were provided with the same resources to access Weight Watchers, no data was available about the uptake of this. An administrative error within Weight Watchers UK prevented me from being able to access data on the number of Weight Watchers meetings that participants attended. This data may have shown that engagement with the Weight Watchers programme, as measured by number of meetings attended, could have moderated the effects seen above. Future work should aim to collect this data so it may be considered in analyses.

The use of a median split to categorise high and low hedonic hunger groups could be refined in larger samples. Selecting cut offs based on extremes of the distribution of PFS scores would be appropriate in a larger sample. The median split

approach was adopted in this study to preserve statistical power, as the sample size available for analyses involving eye movement data was reduced. A larger sample would allow for a more sophisticated means of portioning participants in to high and low hedonic hunger groups.

An additional limitation of this study relates to the lack of control over fed or fasted condition when participants attended the laboratory. Participants were not issued any specific instructions regarding fasting prior to attending study sessions. The reason for this was partly logistical, as testing sessions were scheduled according to participant and laboratory availability. Furthermore, Doolan et al. (2014) did not report an effect of satiety on AB in their study, and the analyses described in Section 2.3.9 showed no effect of overnight fasting on PFS scores, so it can be argued that the current results are unlikely to have been influenced by fasting status. However, Castellanos et al. (2009) report a correlation between subjective hunger and AB in overweight/obese subjects. Whether or not fasting state has an effect on AB is unclear in the literature, therefore future work should seek to maintain consistency, or compare AB-PFS relationships between fasted and fed states, in order to confirm that fasting state does not influence results.

A final limitation of this study is the reduced amount of GD AB data collected, compared to RT AB data. The reasons for this related to participant compatibility with laboratory equipment (participants wearing spectacles) and

equipment failure. The analyses of GD AB data may therefore be underpowered and future work should ensure data collection is more successful so that the amount of data available for analysis is not compromised in this way.

Strengths and future directions

The distinction between HC and LC foods in the visual probe task was a strength of this study. By distinguishing between food types, subtle differences in AB and the relationship with hedonic hunger could be explored. No significant results were seen in the analyses which included AB to food stimuli collapsed across HC and LC, so, without this distinction, the relationships described in this chapter would not have been seen.

A further strength of this study is the combination of RT and GD AB measures. Christiansen et al. (2015) remark that eye movement recordings (GD AB) provide a more reliable assessment of AB than RT recordings, so by assessing RT and GD AB the current study provides a more comprehensive assessment of AB than if only RT AB had been measured. Future work should seek to improve on this even further by following Christiansen and colleague's suggestion that AB tasks should use stimuli that has been personalised for each participant, so that they reflect food items that are maximally salient to the participant.

An additional strength of the current study is the use of Weight Watchers as the behavioural weight management intervention. As stated in Chapters 1 and 3,

Weight Watchers is one of the most commonly used commercial weight management interventions in the UK, and so the weight loss and changes in hedonic hunger and AB may be reflective of what can be expected in a wider sample. Furthermore, use of Weight Watchers as the weight loss intervention in this study allows for comparisons between these results and those of Chapter 3, as was discussed above.

Summary

The current study assessed the relationship between hedonic hunger and AB to food cues during behavioural weight loss. No cross sectional relationship between hedonic hunger and AB was observed, however, exploratory analyses revealed a relationship between change in hedonic hunger and change in AB to HC foods in participants who were classified at baseline as having high hedonic hunger. No relationships between changes in hedonic hunger and changes in AB were seen in participants classified as having low hedonic hunger. Furthermore, no evidence for a relationship between change in hedonic hunger and change in BMI was observed.

The relationship between changes hedonic hunger and changes in AB to HC foods in participants with high hedonic hunger group suggests that an intervention that targets AB may be beneficial in changing hedonic hunger. To our knowledge, no interventions aimed at targeting hedonic hunger have been described, however,

attentional bias retraining (ABR) has been shown to reduce AB and subsequent food consumption (Kemps, Tiggemann, & Elford, 2015). In light of this, in Chapter 5, I explored the feasibility and potential effectiveness of using ABR to reduce AB, hedonic hunger and food consumption in individuals identified as having elevated hedonic hunger.

Chapter 5 - Using attentional bias retraining to reduce hedonic hunger and/or food consumption in individuals with high levels of hedonic hunger: a feasibility study

5.1. Introduction

The findings presented in Chapter 3 indicate that change in hedonic hunger during initial weight loss predicts future BMI. Chapter 3 also showed that a short behavioural weight management programme (12 weeks of Weight Watchers) was less effective for weight loss between baseline and 12 months for individuals with high hedonic hunger, than for those with low hedonic hunger. However, it also showed that the behavioural programme we evaluated did not have an intervention-specific effect on hedonic hunger. New interventions that specifically provide dieters with a means of reducing or managing hedonic hunger could improve weight management efforts.

Although hedonic hunger has been identified as a potential target for weight loss interventions (Lowe & Butryn, 2007), little is currently known about interventions that directly target this phenomenon. The findings presented in Chapter 4 explored potential behavioural correlates of hedonic hunger and suggest that during a weight loss diet there may be an association between changes in hedonic hunger and changes in attentional bias toward food cues – such that among dieters with high hedonic hunger at baseline, reductions in attentional bias toward food cues were associated with reductions in hedonic hunger. From these

results, it is reasonable to hypothesise that an intervention that focuses on reducing reactivity to the food environment, as a means of reducing hedonic hunger, may be a promising avenue of investigation. One way of doing this may be through retraining attention away from rewarding cues – so called 'attentional bias retraining' (ABR).

As discussed in Chapter 1, several studies have shown a positive impact of ABR on subsequent food intake in adults (Dickson et al, 2016, Boutelle et al., 2016, Schumacher et al., 2016; Kakoschke et al., 2014; Kemps, Tiggemann, Orr, et al., 2014; Werthmann et al., 2014a), and these studies support the use of ABR programmes as a means of altering attentional bias and subsequent consumption. Findings from Kemps et al. (2014) suggest that a single session of computer-based ABR was adequate to produce an immediate reduction in attentional bias and that the effects of this training were not limited to the specific stimuli used in the training. Also, Boutelle, Monreal, Strong, and Amir (2016) have recently reported the results of a small (n = 9) ABR intervention study that showed a reduction in AB and PFS subscale scores during an 8-week intervention in participants who report binge eating behaviours. While this is promising for the use of ABR in targeting hedonic hunger and AB, Boutelle et al. (2016) do not report PFS total scores (an indicator of hedonic hunger), so how their intervention affects hedonic hunger overall cannot be inferred. Furthermore, the authors do not speculate as to how the intervention achieved reductions in PFS subscale scores. Finally, psycho-educational leaflets were also provided to participants as part of the intervention, making it difficult to attribute findings to ABR alone. Taken together, the current literature surrounding ABR and

its effects on AB, food intake and (potentially) hedonic hunger seem to provide support for the use of ABR as an intervention, however, more extensive work that replicates these findings, and assesses the feasibility of doing so, is needed. The study described in this chapter aimed to contribute first evidence relating to this by targeting those with heightened hedonic hunger in an ABR intervention. Therefore, the current study attempted to expand upon previous investigations by assessing the feasibility and effects of ABR in individuals with high hedonic hunger and addressing methodological issues with previous ABR studies.

Given that the current body of literature indicates that ABR procedures effectively reduce attentional bias and subsequent food intake (Section 1.6.3.2.3), the current study aimed to adapt this to specifically target hedonic hunger. The mechanisms through which attentional bias modification procedures work is still partly unexplained, but the reductions in attentional bias seen in successful procedures could be due to the ABR procedure altering the perceived valence of the cue (e.g., reducing the positive valence paired to a chocolate cue: Field et al., 2016a). For example, by repeatedly directing participants' attention away from chocolate cues and towards neutral cues, the conditioned response to automatically orient attention to the chocolate cue because of its higher rewarding value may be weakened.

Chocolate is a common choice of stimuli and snack food for attentional bias retraining studies (Kemps, Tiggemann, Orr, et al., 2014; Werthmann et al., 2014). In the UK, chocolate is heavily marketed (e.g., Boyland, Harrold, Kirkham, & Halford, 2011) and is listed as one of the most commonly consumed options for snacks in

the UK and Ireland (Irish Food Board, 2014). The high calorie, sugar and fat content of chocolate also make it a target for reducing consumption (e.g., Tedstone et al., 2017), as excessive consumption of chocolate can lead to weight gain (e.g., Greenberg, Buijsse, Perkins, Fitzgerald, & Adams, 2013). Chocolate also represents a highly palatable sweet food that is commonly craved by females (Hetherington & MacDiarmid, 1993) and regularly eaten by an estimated 90% of UK consumers (Mintel International Group Ltd., 2016). Support for the use of chocolate as a target food for ABR comes from previous research on hedonic hunger, ABR, and from the wider public health literature. Previous findings have linked heightened hedonic hunger to increased chocolate craving (Forman et al., 2007) and chocolate-focussed ABR paradigms can influence consumption of chocolate (Werthmann et al., 2014; Kemps, Tiggemann, & Elford, 2015) and chocolate-based foods (Kemps et al., 2014), therefore chocolate appears to be a viable target food for an attentional bias retraining procedure in individuals with heightened hedonic hunger. As a result, the current study recruited participants who self-identified as liking chocolate and being regular consumers of chocolate products to ensure that the cues used in the attentional bias task and retraining procedure were maximally salient to participants.

The current study aims to address the limitations of the investigations discussed in Section 1.6.3.2.2.. A key consideration in the design was to have multiple training sessions. Previous studies have delivered training and assessed outcomes in a single experimental session and did not assess the longevity of the effect the training has on food consumption. (Boutelle et al., 2014; Hardman et al., 2013; Kakoschke et al., 2014; Kemps, Tiggemann, & Hollitt, 2014; Kemps,

Tiggemann, Orr, et al., 2014; Werthmann, Field, Roefs, Nederkoorn, & Jansen, 2014). One exception of note was Kemps et al. (2015, published after the collection of the current data) who showed sustained effects of ABR in reducing AB to chocolate cues and consumption of chocolate muffin after multiple, but not single, training sessions. Kemps et al. (2015) compared a single and 5-weekly ABR sessions and found reductions in AB and chocolate muffin consumption post-intervention and at 7-day follow-up. Similarly to Kemps et al. (2015), the current study attempted to address these limitations directly by extending the training phase of existing attentional bias modification paradigms to a minimum of five days. Self-reported and laboratory-based intake of palatable snack foods were also assessed before training, immediately after training is complete and then one week following training (self-report only). This was done to examine whether any effects of attentional bias retraining would be observed on food intake seen immediately after the training phase, and if such effects were maintained once training has been completed.

A further limitation of previous studies is the lack of information about how training effects generalise to other types of food. In addition to studying the effects of training on chocolate intake, the current study also assessed intake of potato crisps. These represent a high fat, savoury snack food that is highly popular in the United Kingdom (European Snacks Association, 2014). Assessing potato crisp intake identifies whether any effects of attentional bias retraining seen on chocolate consumption generalise to a non-target food item. This is important because tempting, unhealthy foods in the wider food environment are not limited to one

class of snack food (chocolate), so in order to build evidence for the use of ABR as a method of reducing hedonic hunger, AB and food intake, evidence that effects generalise beyond the target foods is needed.

A further advance of this study is the use of eye-tracking methodology to measure AB, in addition to the use of reaction times to (RT) a visual probe. This yields two methods of assessing AB: indirectly via RT's and directly via gaze dwell times (GD, calculated from eye movement recordings). Findings from the addiction literature have questioned the sensitivity and reliability of RT measures to asses AB, and some have suggested that GD measures may be a more reliable means of detecting the allocation of attention (e.g., Field, Eastwood, Bradley, & Mogg, 2006; Marks, Pike, Stoops, & Rush, 2014). The proposed advantage of GD over RT in determining AB has recently been tested by Christiansen, Mansfield, Duckworth, Field, and Jones (2015). Christiansen et al. (2015) assessed AB to general and personalised (to each participant's preference) alcohol stimuli using RT and GD measures of AB. They concluded that a GD measure of AB had greater internal reliability than RT indexes of AB, and personalised stimuli improved the reliability of AB indexes. Christiansen et al. (2015) recommend that future research incorporate eye movement recordings and personalised stimuli to assessments of AB to ensure their reliability. In line with this, the current study used an eye-tracker to assess GD AB alongside RT measures to improve the reliability of the visual probe task used in the study.

A final limitation identified in previous food-related ABR studies relates to the environment in which the training phase of the study takes place. Each of the

previously described studies that assessed the effects of ABR on subsequent food intake in adults (Kakoschke et al., 2014; Kemps, Tiggemann, Orr, et al., 2014; Werthmann et al., 2014a) required participants to complete training within the laboratory. Whilst this was arguably effective, given the promising results shown by these studies, evidence from the addiction literature suggests training that takes places in an environment in which an individual is likely to be exposed to food cues and temptation may be required for ABR procedures to achieve their maximum effectiveness. McGeary, Meadows, Amir and Gibb (2014) used a month-long, home-based attentional modification procedure similar to a visual probe task in heavy drinking students. Their results showed that while participants assigned to the attentional bias modification programme reported a reduction in the number of days they consumed an alcoholic drink in the preceding seven days (as measured by self-report), those in the control intervention did not. In contrast to laboratory-based retraining procedures, allowing participants to complete the training phase in an environment of their choice (e.g., home) - that likely contains their own, personal food cues that may already be associated with food intake - may enhance the effects of the training. Lowe and Butryn (2007) have already indicated that the personal food environment may be a target for interventions aimed at managing hedonic hunger and food cue reactivity. Therefore, by conducting the training phase of the current study in this environment, we hoped to increase the ecological validity of the ABR procedure. An additional aim of this was to reduce participant burden by removing the need for additional visits to the laboratory, thereby increasing the likelihood of compliance and participant retention.

5.2. Aims of the current study

In an attempt to improve upon previous methodology, a feasibility study was conducted. The overall aim was to assess the feasibility of using multi-session home-based ABR to reduce attentional bias, hedonic hunger and chocolate consumption in non-dieting individuals with elevated levels of hedonic hunger. The aims of this study were:

Feasibility aims

1. To assess whether we could successfully recruit non-dieting women with high levels of hedonic hunger to participate in this study
2. To assess whether participants were able to complete the home-based ABR intervention.
3. To assess whether we could successfully use eye movement recordings to measure attentional bias.
4. To assess the potential effectiveness of the home-based ABR.

To achieve these aims the following hypotheses were tested:

- *Hypothesis 1*. Participants in the attentional bias retraining condition will show reduced attentional bias to chocolate cues following the attentional bias retraining procedure relative to the control group.

- *Hypothesis 2*. Participants in the attentional bias retraining condition will show a reduction in hedonic hunger scores (as measured by the Power of Food Scale) following the retraining procedure, relative to the control group.

- *Hypothesis 3*. Participants in the attentional bias retraining condition will show reduced chocolate consumption between Visit 1 and Visit 2, relative to the control group.

- *Hypothesis 4*. Participants in the attentional bias retraining condition will show reduced potato crisp consumption between Visit 1 and Visit 2, relative to the control group.

- *Hypothesis 5*. Participants in the attentional bias retraining condition will report reduced frequency of self-reported chocolate consumption between Visit 1 and Visit 2 relative to the control group.

To assess the potential effectiveness of home-based ABR, I analysed the data for each hypothesis in the normal way, but focussed on the size and direction of effects rather than the statistical significance.

5.3. Method

5.3.1. Study Design

Forty females with overweight, obesity or normal weight who also had elevated levels of hedonic hunger (Power of food scale (PFS) score above 3) were randomly assigned to either a control group (n=20) or a multi-session, home-based attentional bias retaining procedure (n=20). The retraining procedure consisted of 5 sessions over 7 days. Attentional bias, hedonic hunger, and consumption of highly

palatable snack foods were assessed in the laboratory at baseline (Visit 1) and after the retraining procedure was completed (Visit 2; 7 days after Visit 1).

This study was a 2 (training condition: control training or attentional bias retraining) × 2 (time: Visit 1, Visit 2) mixed design. The independent variable was the training condition. Dependent variables were change in attentional bias, change in hedonic hunger, change in chocolate consumption, and change in potato crisp consumption. Participants were randomly allocated to control or attentional bias retraining conditions at the beginning of the first laboratory testing session, using an online random number sequence generator (www.random.org).

Previous authors (Werthmann et al., 2014) have suggested that an adapted anti-saccade task is superior to a visual probe task when assessing indirect indexes of attentional bias (via eye movement recordings) and when attempting to retrain attentional bias. Whilst an interesting point, the authors may have made this suggestion due to their observation that retraining success was dependent on task accuracy in their study. This would be an important consideration for the current study if participants would be sourced from a population not accustomed to computer use but, given that an eligibility criterion for the current study relates to at-home computer use, this is unlikely to be problematic in the current sample. Furthermore, task accuracy in Chapter 4 was high – no participant had a task accuracy rate below 90%. Given the similarities between the visual probe task used in the current study and Chapter 5, accuracy rates were not expected to be problematic or compromise the effects of any attentional bias retraining that occurred.

5.3.2. Participants

Forty-nine female participants were recruited via opportunity sampling to a study described as an investigation into "the link between attention and taste perception". Non-dieting individuals were recruited so that the assessment of food intake in this study would not be affected by participants restricting their intake to reduce their weight. Study advertisements were placed around the University of Liverpool campus and the local area. Participants received a £20 shopping voucher or course credit for their time. Participants were also awarded entries to a prize draw for an additional shopping voucher each time they completed the at-home computer task and if they completed all study procedures. Eligibility criteria were:

- Female

- Aged 18-55 years old

- BMI> 18.5 kg/m^2

- Not currently dieting (not following a structured/commercial/NHS-based weight loss programme)

- Not currently pregnant

- Fluent English speakers

- 20/20 or corrected (not glasses) to 20/20 vision

- No food allergies or intolerances

- Like and regularly consume cake, chocolate, biscuits, potato crisps and chips

- Hedonic hunger score (PFS total score, possible range 1-5) above 3 (this requirement was described to participants as "scoring within a certain range on a questionnaire that assesses their reaction to food").

- Not currently taking part in another appetite-based research study

- Willing to complete a short computer task on their home/work computer on 5 days out of 7

- Willing to attend two laboratory testing sessions

5.3.3. Measures and Procedure

Measures used in this chapter have been described in detail in Chapter 2 (see sections 2.4, and 2.5). A schematic of the study procedure is shown in Figure 5.1. Participants were screened for eligibility via an online survey administered via Qualtrics. This questionnaire assessed hedonic hunger (PFS, Lowe et al., 2009) and the presence of any food allergies or dietary patterns inconsistent with the study (Medical History Questionnaire, Section 2.4.2)., Only eligible participants were invited to attend the laboratory for two sessions, scheduled one week apart. Each session lasted approximately 30-45 minutes. Laboratory sessions were scheduled at the participant's convenience between 11 am to 6 pm on weekdays. Efforts were made to keep the time of day sessions occurred consistent for each participant (i.e. if a participant attended T1 at 12 pm, the ideal time for T2 to be scheduled for 12 pm on the appropriate day). This was achieved, with all T1 and T2 appointments falling within a 55 minute window of the ideal time to be scheduled.

Participants were requested to abstain from eating for at least 90 minutes before attending the laboratory. This was to ensure that participants were not

recently sated and therefore unlikely to consume the study foods. A further reason for this request was to ensure participants were not in such a state of energy deficit that the experimental tasks and PFS captured homeostatic, rather than hedonic, hunger. This is in line with previous suggestions by Lowe and Butryn (2007) that the PFS is not suitable for use in situations where eating-related thoughts are likely attributable to homeostatic hunger and energy deficit.

At the start of the first laboratory visit participants were re-screened for food allergies via the Medical History Questionnaire to confirm the accuracy of their previous responses. No participants were excluded for any reason at this stage. Participants then completed the visual probe task. The task consisted of 8 practice trials, followed by 2 buffer trials and 64 experimental trials. Trials began with a white fixation cross displayed on a black background for 500 ms. This was replaced by the stimulus display of two colour images presented side by side on a black background for 2000ms. Images were chocolate-related items (e.g., chocolate bar, chocolate covered biscuits) or neutral images matched for visual similarity (e.g., a computer keyboard, a storage box). These disappeared and were replaced by a probe, a white arrow pointing up or down. Participants were required to identify the probe by making a spatially compatible key press on the computer keyboard. Stimuli were presented in a new, random order for each participant and probes appeared on the left and right of the screen and replaced chocolate and neutral images with equal frequency. This generated 32 critical trials (probe replaced chocolate) and 32 neutral trials (probe replaced neutral image). An equal amount of "Up" and "Down" probes were presented. Eye movements were recorded during task completion via a desk-

mounted ASL eye-tracker that used a 9-point calibration with a sampling rate of 120Hz during the 2000ms stimulus presentation.

Following the visual probe task participants completed paper versions of the PFS (Lowe et al, 2009), the Chocolate Consumption Questionnaire (Section 2.4.3) to assess chocolate consumption over the preceding 7 days, and Visual Analogue Scales followed by the chocolate taste test and Chocolate Visual Analogue Scales. Participants were not given a time limit for this.

When participants signalled to the experimenter that they had finished the chocolate taste test they were asked to complete a potato crisp taste test. Participants were not told in advance that they would have a second taste test or that they would be asked to rate potato crisps in addition to chocolate. This was to ensure they didn't adjust or reduce their intake during the chocolate taste test in anticipation of a second taste test. The potato crisp taste test followed the same procedure as the chocolate taste test with participants using the Potato Crisp Visual Analogue Scales to provide taste ratings. Upon completion of the second taste test participants' height and weight were measured and they were provided with the Study Checklist (example shown in Appendix 25). The Study Checklist was a paper-based checklist of what participants were required to do during the days between the two laboratory visits. This was provided as an additional measure to encourage compliance with study procedures. The ABR intervention began the day following the T1 appointment. The ABR intervention is described in Section 5.2.4.

Approximately one week (*mean* = 7.05 days, range 7-9 days) after Visit 1 participants attended Visit 2. Participants completed the visual probe task with

concurrent eye movement recording, PFS and VAS, chocolate and potato crisp taste tests and had their body weight measured. This session lasted approximately 30 minutes.

Seven days after they attended Visit 2, participants were emailed a link to an online follow-up questionnaire. They completed the Chocolate Consumption Questionnaire (Section2.4.3) and were asked what they thought the aim of the study was (free text answer). This was followed a verbal debriefing. The follow-up questionnaire was completed via Qualtrics. Following this, participants received a £20 online shopping voucher via email. Participants who completed all study procedures training sessions and study procedures were also entered in to the prize draw. Participants also received additional entries to the prize draw for each online training task they completed (1 entry per task completed).

5.3.4. ABR Intervention

Participants were randomly assigned to either the ABR intervention group or control group. They were asked to complete their assigned ABR task on five of the seven days in the week between the first laboratory (T1) visit and the second laboratory visit (T2). The task was administered by Inquisit Web (Milisecond Software, Seattle, WA) and participants received daily emails directing them to the website hosting the appropriate online task. Each online training session took approximately 7-10 minutes. Participants were able to complete the home-based training sessions and online questionnaires at their convenience. Rate of task completion was acceptable-to-good (*mean* = 4.92, range 3-6 sessions completed)

and comparable to the rate of completed sessions reported by McGeary et al. (2014).

The task administered to the ABR intervention group was designed to direct attention away from chocolate cues. The task consisted of the same stimuli, trial structure and instructions as the visual probe task administered in the T1 and T2 laboratory sessions, however the locations of the visual probe that participants were instructed to respond to was manipulated. The visual probe (the arrow) replaced the neutral image on every trial. Probes appeared on the left and right of the screen with equal frequency and an equal amount of "Up" and "Down" probes were presented.

The task administered to the control group was identical to the visual probe task administered in the laboratory sessions. The location of the probe was not manipulated and replaced chocolate and neutral images with equal frequency. The task was not designed to manipulate attention.
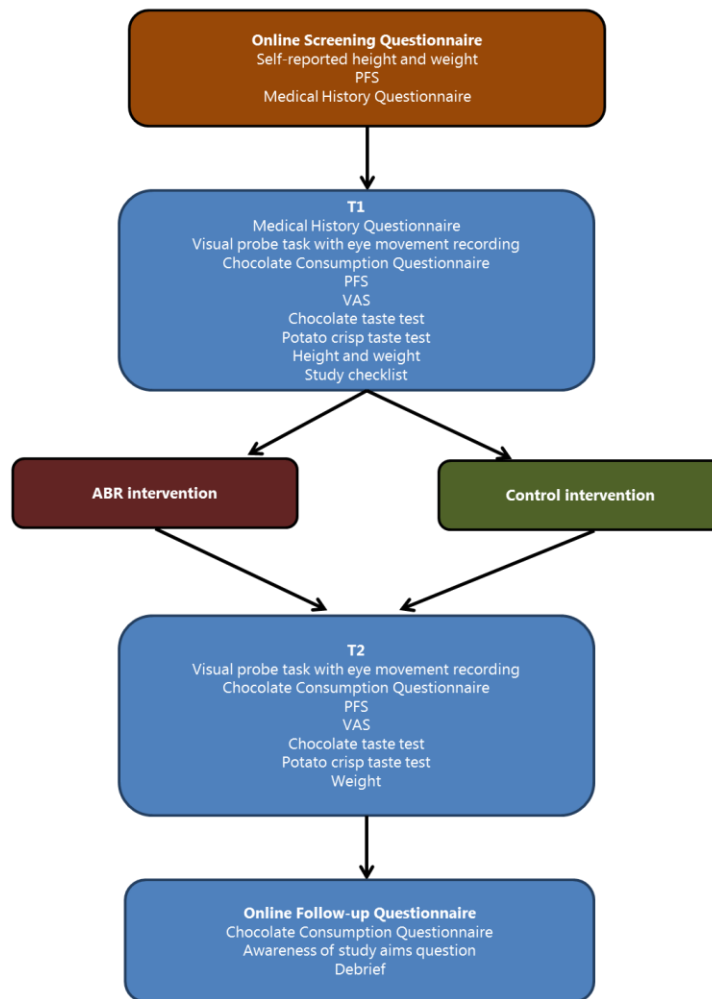
Figure 5.1 Schematic of the study procedure.

Although chocolate consumption was the main focus of the food intake part of the study, potato crisp consumption was also measured to investigate if any effects of attentional bias retraining generalised to an additional food type. To achieve this without compromising the measure of chocolate intake (participants may restrict chocolate intake to compensate for other, upcoming, food intake), participants were informed upon recruitment to the study that they may be asked to rate a random selection of up to two of five possible snack foods and given a bogus list of possible foods with chocolate and potato crisps embedded in the list. During the laboratory sessions, they were presented with the chocolate taste test first but not informed of or asked to complete the potato crisp taste test until they completed the chocolate taste test. Participants were also asked not to eat for up to 90 minutes before the laboratory sessions to induce a moderate level of hunger, thus making them likely able to complete both taste tests.

Methods to increase compliance

Boyland, Randall-Smith, & Jones (unpublished data) used a similar visual probe task and ABR procedure to the current study. Boyland et al. encouraged compliance by emailing participants daily to remind them to complete the online training task. They reported poor levels of compliance with the home—based training task among their participants, with participants completing fewer online training tasks than required (mean = 3.55, range = 0-5). In light of this, three additional measures were taken to encourage compliance in the current study. Firstly, participants were issued with a "Study Checklist" (Appendix 25) at their first laboratory visit. This was a slip that detailed what was required of the participants

over the seven days following the first laboratory visit and allowed them to check off each part of the study as it was completed. This also included researcher contact details for queries and the date of their second laboratory session. Participants were encouraged to keep this checklist somewhere they would see it, such as on their desk, in their diary etc. Secondly, participants received email reminders to complete the home-based training tasks. Finally, participants were made aware that the financial reimbursement would be provided upon completion of all study procedures (therefore after the seven day follow up questionnaire was completed). An additional incentive was also offered in the form of a prize draw – participants were informed when they began the study those participants who completed all study procedures would be entered into a prize draw to win an additional online shopping voucher. They were informed that each time they completed the online task they would be entered in to the prize draw once, so if they completed the task five times their name would be entered in to the draw five times (one entry for completing all study procedures plus one entry per completion of each of the five online tasks, resulting in a maximum of six entries per participant).

5.3.5. Ethical Issues

There were several potential ethical issues that arose in this study. The study involved deception in that the true aim of study was concealed from participants. Participants joined the study believing that the study was investigating a link between taste perception and attention. This was necessary in order to assess changes in attentional bias and chocolate intake. Making participants aware of the true nature of the experiment may have influenced their behaviour as they may have

deliberately tried to avoid/attend to chocolate stimuli or may have consciously increased or decreased their food consumption. Furthermore, the nature of the taste tests and deliberate order in which they were presented involved misleading participants. Participants were under the impression that at any laboratory testing session they could be asked to taste up to two of the five possible foods, but they were always asked to taste chocolate buttons and then potato crisps. Again, this was necessary to ensure that participants did not deliberately alter their eating behaviour, thus contaminating the *ad libitum* consumption measure. To counter this, participants were fully debriefed upon completion of the study and invited to ask any questions that they may have had. They were also able to withdraw their data after taking part in the study, should they have wished to, although no participants requested this.

5.3.6. Awareness of Study Aims

At the end of the follow-up questionnaire participants were asked to state what they thought the aim of the study was. Thirty-nine of the forty participants completed the follow-up questionnaire and provided an answer. Three participants indicated that they were aware of the difference in the location of the visual probe in the home-based tasks compared to the laboratory-based tasks and thought this was to manipulate their attention, although none related this to hedonic hunger or change in chocolate or crisp consumption. No participants guessed the full aim of the study so no data was removed from analyses because of awareness of the study aims.

5.4. Results

Prior to analysis, reaction time (RT) data were subjected to trimming procedures similar to those used by Christiansen et al. (2015) and Lattimore and Mead (2015). Before trimming began, a missing data threshold of 10 % was decided, whereby any participant losing more than 10 % of their RT data from trimming would be removed from analyses. RTs faster than 200 ms and slower than 2000 ms, RTs beyond 2.5 standard deviations of each participant's mean RT and trials on which errors were made were removed prior to analysis. No participant breached the missing data threshold and RT data from all 40 participants was retained for analyses. RT bias was calculated by subtracting mean RT on trials where the visual probe replaced the chocolate cue from meant RT from trials where the visual probe replaced the neutral cue. Positive scores indicate AB.

Gaze dwell (GD) times (the length of time participants fixated on either the chocolate or non-chocolate image) for chocolate and control images were extracted from eye movement recordings. GD times represent the total amount of time (in ms) participants fixated on the chocolate cue and the neutral cue. GD bias is the difference between these two measures. Eye movements were classed as a fixation if they remained stable for at least 100 ms and within one degree of visual angle. GD bias was calculated by subtracting dwell time on neutral images from dwell time on chocolate images. These parameters are identical to those used in Christiansen et al (2015), who employed a similar task design to that used in the current study.

5.4.1. Recruitment of Eligible Participants

Forty-nine participants were recruited. Data from nine participants are not included in the analyses. Reasons for exclusion were: the participant withdrew from the study before or shortly after they completed the first at-home computer task (3 participants); the participant did not complete the minimum of 3 at-home computer tasks (3 participants); the participant's PFS total score measured in the laboratory was below 3 (3 participants). This yielded a final sample of forty female participants who had a mean age of 26.8 years (*s.d.* = 9.2) and a mean baseline BMI of 26.9kg/m^2 (*s.d.* = 5.5).

5.4.2. Completion of home-based ABR training

The number of online training sessions completed by participants was acceptable-to-good (*mean* = 4.92, range 3-6 sessions completed), with most participants completing the required number of online trainings, or close to the required number.

5.4.3. Compliance with study protocol

Gaze dwell bias scores were available for 25 of the 40 participants. Reasons for missing data were: equipment or recording failure during one or more laboratory testing sessions (12 participants); and participants not making fixations on the stimulus display during > 90 % of trials (3 participants).

PFS score were calculated as described in Chapter 2. Self-reported chocolate consumption frequency was calculated by totalling the number of days participants

reported eating chocolate on the Chocolate Consumption Questionnaire. The same calculation procedure was followed for both the laboratory-based and online (follow-up) versions of the questionnaire. Thirty-nine of forty participants completed the follow-up questionnaire.

Thirty-six of forty participants provided valid hunger VAS scores. Hunger scores were obtained by measuring the distance between the left point of the horizontal VAS line, anchored 0, "Not at all hungry", and the point at which the participant placed a vertical mark. Measurements were taken in millimetres (mm) and corresponded to the hunger score, for example, a measurement of 49 mm would equate to a hunger score of 49. Hunger as measured by VAS indicated that participants were not experiencing levels of hunger consistent with a fasted state (Table 5.1). Ratings of hunger were not correlated with measures of attentional bias or calories consumed from chocolate or potato crisps at T1 (all p's > .05), suggesting hunger did not influence T1 measures of attentional bias or food consumption. All participants reported not having eaten during the 90 minutes preceding the experiment (Table 5.1). This was in accordance with pre-study instructions given to participants. The levels of hunger and time elapsed since eating prior to attending the experimental session reported by participants in this study were consistent with Lowe et al.'s (2007) recommendation.

Table 5.1 Hunger ratings and number minute elapsed since participants reported last eating.

	Range	Mean	Standard deviation
T1 Hunger VAS rating	13 – 95	64.4	20.7
T2 Hunger VAS rating	4 – 98	62.4	24.9
T1 Minutes elapsed since last eaten	125 – 975	284.1	246.9
T2 Minutes elapsed since last eaten	97 – 838	246.2	186.4

Note. VAS =Visual Analogue Scale. T1 = baseline, pre-intervention laboratory session. T2 = the follow-up, post-intervention laboratory session.

5.4.4. Potential effectiveness of the intervention

Participant characteristics

Participant characteristics, chocolate consumption, crisp consumption, number of training sessions competed and the days between T1 and T2 are displayed in Table 5.2. Participants in each condition were well matched at T1 with no significant differences in age, T1 BMI, PFS total score, or chocolate and crisp consumption observed between groups (all p's>.05). Participants were also well matched for baseline AB measures (all p's>.05; see Table 5.2).

Table 5.2 Participant characteristics displayed by condition.

	ABR Group (n=20)		Control Group (n=20)	
	Mean	Standard deviation	Mean	Standard deviation
Age (years)	28.8	10.1	24.8	7.9
T1 BMI	27.5	5.6	26.3	5.4
T2 BMI	27.4	5.6	26.3	5.4
T1 PFS total score	3.9	.5	3.8	.6
T2 PFS total score	3.8	.5	3.8	.6
T1 Amount of chocolate consumed (g)	44.2	36.6	29.6	22.4
T2 Amount of chocolate consumed (g)	44.0	32.1	34.6	31.7
T1 Calories from chocolate consumed (kcal)	234.0	193.9	156.9	118.5
T2 Calories from chocolate consumed (kcal)	233.2	169.9	183.7	168.1
T1 Amount of crisps consumed (g)	11.7	13.3	9.7	5.5
T2 Amount of crisps consumed (g)	13.4	14.4	12.7	8.0
T1 Calories from crisps consumed (kcal)	61.6	70.2	51.2	29.1
T2 Calories from crisps consumed (kcal)	70.7	75.6	66.7	42.0

Note. BMI = Body Mass Index. T1 = baseline, pre-intervention laboratory session. T2 = the follow-up, post-intervention laboratory session.

Data preparation

Data were assessed for adherence to assumptions of normality using the Kolmogorow-Smirnov test. Reaction time AB data, T2 dwell bias data from the ABR condition, chocolate consumption and crisp consumption data were not normally distributed. These data were log transformed to correct this before being submitted to parametric analyses. Original, untransformed data are reported for clarity. All analyses were conducted using IBM SPSS version 22 for Windows (IBM SPSS Inc., Chicago, USA). The threshold for significance was $p<.05$.

5.4.5. Hypothesis testing

Hypothesis 1. Participants in the attentional bias retraining condition will show reduced attentional bias to chocolate cues following the attentional bias retraining procedure.

Reaction time attentional bias data were submitted to a 2 (Time: Visit 1, Visit 2) x 2 (Condition: ABR, Control) mixed ANOVA. Results showed no main effect of time ($F(1,19) = .44$, $p=.51$, $\eta_p^2 = .02$), condition ($F(1,19) = 3.96$, $p=.06$, $\eta_p^2 = .17$) or time x condition interaction ($F(1,19) = .53$, $p=.48$, $\eta_p^2 = .03$). This pattern of results was also observed when the analysis was repeated with the gaze dwell bias data. That analysis found no main effect of time ($F(1,6) = .78$, $p=.41$, $\eta_p^2 =.12$), condition ($F(1,6) = 1.25$, $p=.31$, $\eta_p^2 =.17$) or time x condition interaction ($F(1, 6) = 1.27$, $p=.30$, $\eta_p^2 =.18$).

Table 5.3 AB scores for T1 and T2 by condition.

	ABR Group n=20		Control Group n=20	
	Mean	Standard deviation	Mean	Standard deviation
T1 RT Bias (ms)	3.9	28.7	14.5	29.4
T2 RT Bias (ms)	-4.3	46.4	13.9	28.6
T1 Gaze dwell bias (ms)	72.9	175.3	100.3	125.6
T2 Gaze dwell bias (ms)	16.2	276.9	126.3	162.1

Note. RT =reaction time; ms = millisecond.

Hypothesis 2. Participants in the attentional bias retraining condition will show a reduction in hedonic hunger scores (as measured by the Power of Food Scale) following the retraining procedure, relative to the control group.

PFS total scores were submitted to a 2 (Time: Visit 1, Visit 2) x 2 (Condition: ABR, Control) mixed ANOVA. Results showed no main effect of time ($F(1,19) = 1.1$, $p=.31$, $\eta_p^2 = .05$), condition ($F(1,19) = .00$, $p=.99$, $\eta_p^2 =.00$) or time x condition interaction ($F(1,19) = 1.1$, $p=.31$, $\eta_p^2 =.05$). This indicates no effect of the ABR intervention on PFS total score in the ABR group relative to the control group.

Hypothesis 3. Participants in the attentional bias retraining condition will show reduced chocolate consumption between Visit 1 and Visit 2, whereas no change will be observed in participants in the control condition.

The amount of chocolate that participants consumed (grams) in the laboratory taste tests was submitted to a 2 (Time: Visit 1, Visit 2) x 2 (Condition: ABR, Control) mixed ANOVA. Results showed no main effect of time ($F(1,19) = .17$, $p=.69$, $\eta_p^2 =.01$), condition ($F(1,19) = .72$, $p=.41$, $\eta_p^2 =.04$) or time x condition interaction ($F(1,19) = .09$, $p=.77$, $\eta_p^2 =.01$). This indicates no effect of the ABR intervention on chocolate consumption in the ABR group relative to the control group, therefore Hypothesis 3 is not supported.

Hypothesis 4. Participants in the attentional bias retraining condition will show reduced potato crisp consumption between Visit 1 and Visit 2, whereas no change will be observed in participants in the control condition.

The amount of potato crisps participants consumed (grams) in laboratory sessions was submitted to a 2 (Time: Visit 1, Visit 2) x 2 (Condition: ABR, Control) mixed ANOVA. Results showed a significant main effect of time ($F(1,19) = 8.05$, $p=.01$, $\eta_p^2=.31$). No main effect of condition ($F(1,19) = .31$, $p=.58$, $\eta_p^2=.02$) or time x condition interaction ($F(1,19) = .04$, $p=.88$, $\eta_p^2=.00$) were observed. A post-hoc paired samples t-test of potato crisp consumption at Visit 1 and Visit 2 revealed that across both conditions, participants ate more potato crisps at Visit 2 (*mean*=13.06g, *s.d.*=11.48) than they did at Visit 1 (*mean*=10.71g, *s.d.*=10.13; $t(39)=-2.842$, $p=.007$, *d*=.22). This is a difference of 2.35g or 12.36 kcal. Despite the main effect of time, this analysis indicates no effect of the ABR intervention on potato crisp consumption in the ABR group relative to the control group, therefore Hypothesis 4 is not supported.

Hypothesis 5. Participants in the attentional bias retraining condition will report reduced frequency of self-reported chocolate consumption between Visit 1 and Visit 2 relative to the control group.

Frequency of self-reported chocolate consumption was calculated as the number of days on which participants reported eating chocolate, as measured by the Chocolate Consumption Questionnaire (Appendix 9). These data were submitted to a 2 (Time: Visit 1, Visit 2) x 2 (Condition: ABR, Control) mixed ANOVA. Results showed a significant main effect of time ($F(1,18) = 6.85$, $p=.02$, $\eta_p^2= .28$). No main effect of condition ($F(1,18) = .11$, $p=.31$, $\eta_p^2=.06$) or time x condition interaction ($F(1,18) = 1.30$, $p=.27$, $\eta_p^2= .07$) were observed.

The main effect of time suggests that all participants reported lower self-reported chocolate consumption at follow up compared to baseline, irrespective of experimental condition (ABR or control). Further analysis of the main effect of time revealed that all participants reported eating chocolate on fewer days during the week between T2 and follow-up (*mean* =4.33, *s.d.* =1.89) than they did during the week preceding their T1 appointment (*mean* = 5, *s.d.* = 1.54; $t(38) = 2.86$, $p = .007$, $\eta_p^2 = .40$). Despite the main effect of time, this analysis indicates no effect of the ABR intervention on frequency of self-reported chocolate consumption in the ABR group relative to the control group, therefore Hypothesis 5 is not supported.

5.5. Discussion

The overarching aim of this study was to provide a first exploration of the feasibility of using a 5-day home-based ABR to reduce attentional bias, hedonic

hunger and chocolate intake in individuals with high hedonic hunger. Assessment of the aims set out in Section 5.2 indicates the ABR intervention is feasible. The proposed numbers of participants were recruited to the study and compliance with the study protocol and measures was acceptable. A number of participants were excluded from analyses because of poor rate on online training completion, but the required number of participants was still retained for analysis. Overall, the current study achieved its feasibility aims and, although statistical hypothesis testing offers limited support for the effectiveness of the ABR intervention, this study showed that conducting the ABR intervention is feasible.

Statistical analyses suggest that the ABR intervention may reduce AB for chocolate, but a large trial would be needed to detect a significant effect. Inspection of mean AB scores and effect sizes suggest that AB to chocolate cues decreased in the ABR group, but not in the control group. There was no evidence to suggest that the intervention reduced hedonic hunger or laboratory-assessed or self-reported intake of chocolate. There was also no evidence of any effect of attentional bias retraining on a non-target food item, potato crisps. At face value, these results suggest that a brief (5 sessions-7-day), home-based ABR intervention is not an effective method of targeting hedonic hunger or chocolate intake in individuals with high hedonic hunger.

The suggested potential for an effect of the ABR intervention on attentional bias or food intake in this study appears to be consistent with other recent work in this field. Several studies have shown successful effects of ABR on attentional bias and/or subsequent food intake (Boutelle et al, 2016; Dickson et al, 2016;

Schumacher et al, 2016; ; Kakoschke et al., 2014; Kemps, Tiggemann & Elford, 2015Kemps, Tiggemann, Orr, et al., 2014; Werthmann et al., 2014a). However others found limited or no effects (Becker et al, 2017; Hardman et al, 2015), suggesting that either AB to food is resistant to change, or the methodology used in ABR interventions needs to be refined. The studies cited here vary substantially in their aims and participants, and perhaps most notably, in their methods of assessing and retraining attentional bias, and this may help explain the inconsistencies in findings.

The methods used in previous studies that showed the hypothesised effects of ABR on attentional bias and food intake included a modified visual probe task (Kemps et al, 2015), word-stimuli identification tasks (Boutelle et al., 2014, 2016), and variations of the Approach Avoidance Task (AAT) that have been employed in a similar paradigm (Becker, Jostmann, Wiers, & Holland, 2015; Dickson, Kavanagh, & MacLeod, 2016; Schumacher, Kemps, & Tiggemann, 2016). Methodological differences between these and the current study may explain the lack of statistically significant effects observed in this chapter. Boutelle et al. (2014, 2016) used a word-based visual probe task, where stimuli were food-related and neutral words. Becker et al. (2015), Dickson et al. (2016), and Schumacher et al. (2016) each used the AAT and contrasted approach-chocolate/food and avoid-chocolate/food contingency interventions, whereas the current study compared avoid-chocolate with a neutral-contingent intervention (as did Kemps et al 2015). Furthermore, while the AAT assesses food cue reactivity, it may assess a different aspect of food cue reactivity than what is assessed by a visual probe task. The AAT is also commonly used to measure approach biases, which may differ from attentional biases in the way that

they reflect appetitive motivation. It may be that in order to fully explore the potential for ABR as an intervention, an approach-based intervention arm should be considered alongside an avoid-based and neutrally contingent intervention arm. The ABR seen in studies that contrasted an approach chocolate/food with an avoid chocolate/food condition may be achieving its effect through engagement with the target stimulus category in both experimental conditions. The lack of effects in the current chapter could be due to the "attend neutral" control condition I used not being a strong enough alternative to the inclination to attend chocolate. An AAT condition that requires participants to deliberately approach or avoid chocolate/food stimuli still requires them to engage with it in some way, as participants will need to identify the stimulus to determine which action (approach or avoid) they are required to perform. A similar explanation would apply for the word-based visual probe task used by Boutelle et al. (2014; 2016), as participants would still read the stimulus words during the task, which is arguably a different neural process from viewing image stimuli in an image-based visual probe task. It is also possible that the AAT may be a superior method of assessing and modifying attentional bias because it captures both motivation and attention. These suggestions are highly speculative and more work is needed to ascertain how sensitive ABR is to methodological fluctuations such as those described here.

The results of the current study cannot be used to support those presented in Chapter 4. Chapter 4 showed that there was no baseline (pre-intervention) relationship between hedonic hunger and AB to food cues, but change in hedonic hunger was associated with change in AB over 12 weeks, particularly in those with

high hedonic hunger. The ABR intervention in this study did not change AB or hedonic hunger, so the relationships uncovered in Chapter 4 cannot be confirmed. One possible explanation for the difference in findings across the studies is consistent with the predictions about the relationship between attentional bias and food that were made by Field, Werthman, Franken, Hofman, Hogarth and Roefs (2016) in a recent review. Firstly, Field et al (2016) posit that attentional bias is generated when appetitive cues, such as chocolate cues, are evaluated in a positive, negative or ambivalent (both positive and negative) manner. Positive or negative evaluations cause the capture of attention due to their associated physiological arousal, whereas ambivalent evaluations produce motivational conflict, which in turn draws attention.

Motivational conflict occurs because the stimulus is evaluated positively because it is appealing and desired, but also negatively because it is inconsistent with a goal, such as reducing chocolate consumption to maintain a healthy weight. In Chapter 4, participants were weight-conscious and became engaged in a weight loss intervention, so food cues could have been evaluated positively before treatment began and could then have caused motivational conflict once weight loss was underway and weight management procedures were being experienced. These scenarios, in theory, should not apply to the participants included in the current study. Participants in this study were deliberately recruited so as not to be actively dieting, so the chocolate cues should not have produced any particular motivational conflict, however we cannot rule out all possibility that motivational conflict may have occurred. It is plausible that participants may have experienced motivational

conflict as they could have seen chocolate as a challenge to maintaining weight. Some participants in the sample also had overweight, so if they were unhappy with their body size and/or motivated to change this but were not actively dieting, chocolate may have activated motivational conflict. Alternatively, this could suggest that ABR is more effective in people who are motivated to reduce chocolate consumption/lose weight as stimulus evaluation may be more consistent with such people's goals. The current study did not assess potential causes of motivational conflict, so future work should control for possible motivations for chocolate restriction. Furthermore, this explanation is only speculation, however, as it could be suggested that dietary restraint (attempting to limit caloric intake; Stunkard & Messick, 1985) may have influenced the way participants responded to the measures taken in the study.

Whilst dietary restraint is a well-studied topic in the appetite literature (e.g., Werthmann, Jansen, & Roefs, 2014) worth noting when considering the findings of this study, other work would suggest that dietary restraint may not be an explanation for the findings of the current study. Polivy, Coleman and Herman (2005) found that restrained eaters consumed more chocolate than unrestrained eaters in a laboratory setting, although this was after a period of chocolate deprivation. Moreover, in a series of studies, Stice, Fisher and Lowe (2004) found no association between dietary restraint and laboratory food intake. Furthermore, Werthmann et al. (2013) noted no differences in attentional bias to food cues in female restrained and unrestrained eaters. Finally, Finlayson, Cecil, Higgs, Hill, and Hetherington (2012) reported no significant correlation between PFS total scores

(used a measure for hedonic hunger) and scores on a restraint scale in undergraduate women, so the decision not to measure restraint in the current study was justified. This lack of clarity in the potential relationships between dietary restrain and the measures used in the current study warrant further investigation so future work can account for the potential influence (if any) of dietary restraint in interventions targeting AB, hedonic hunger or food intake.

A further potential explanation for the lack of significant findings in the current study relates to the eligibility requirement that participants liked and regularly consumed chocolate; this requirement was disguised amongst being a regular eater of other palatable snack foods to disguise the aim of the study. By not deliberately recruiting or assessing if participants had an exceptionally strong liking for chocolate in particular, the sample may have included participants who didn't display an overly strong positive evaluation of chocolate cues, thus diluting any possible effects of the ABR intervention. Conversely, participants recruited to this study could have had specific chocolate-related food preferences, such as preferring dark chocolate over milk chocolate, or chocolate-flavoured items more than bars of chocolate. The stimuli used in the visual probe task represented a variety of chocolate-related items, so stimuli may not have reflected participants' specific preferences. Indeed, it has recently been shown by Christiansen et al (2015) that personalising stimuli in a visual probe task heightens its internal reliability, so the lack of personalised stimuli in the current study may also have contributed to its potential insensitivity.

A further explanation for the results presented in this chapter may be that the strength of the intervention was not appropriate for the strength of its targets, namely hedonic hunger, attentional bias and chocolate consumption. Hardman et al (2013) previously commented that attentional bias appears to be resistant to change, so the length of the retraining intervention employed in this study may not have been robust enough to change attentional bias. Indeed, some of the positive results from ABR have come from much longer interventions lasting several weeks (Boutelle et al, 2016; Kemps et al, 2015), however, it should be noted that ABR effects have been shown from single-session interventions (see Kemps, Tiggeman & Orr, et al., 2014). Alternatively, as posited by Field et al (2016), and supported by Hardman, Jones, Field and Werthmann (2017), AB may appear resistant to change because it is more "state" like, than "trait" like. Field et al. (2016) and Hardman et al. (2017) propose that AB fluctuates, perhaps even throughout the day, hour etc., in response to motivational states. If the nature of attentional bias is indeed transient, it could be that the non-dieting, non-fasted, regular consumers of palatable foods that comprise the participant sample of the current study were not in an appropriate motivational state to display attentional bias reductions during this study, although motivational state was not assessed in this study beyond "not actively dieting". Other motivational states, such as the desire to maintain weight or limit snack food intake, may have been present in the participants. This is, however, speculation and warrants further investigation, tracking motivation over time throughout a similar experiment.

The results of this study showed that participants consumed more potato crisps at Visit 2 than they did at Visit 1. This is somewhat surprising, although the size of the increase was small (2.35g or 12.36 kcal). This could have occurred because participants expected the potato crisp taste test at T2 after T1, or they may have an increased liking for the potato crisps after being faced with chocolate stimuli so frequently during the study. By repeatedly presenting participants with chocolate cues and asking them to recall their intake of chocolate, the study may have inadvertently triggered a form of sensory-specific satiety for chocolate. Sensory-specific satiety (Hetherington, 1996; Hetherington, Rolls, & Burley, 1989) refers to the phenomenon whereby recent consumption of a particular food produces a decline in perceived pleasantness of that food when it is encountered after a short delay, reducing intake of the food (even after a 1 hour delay, Hetherington, 1996). If some form of sensory-specific satiety to chocolate had been invoked, potato crisp intake may have risen from T1 to T2 because the potato crisps represented a novel (relative to chocolate) food with a markedly different taste and texture to chocolate. The findings that potato crisp intake increased across conditions would support this, as participants in the control condition were exposed to chocolate stimuli in the study as often as those in the ABR group. Further support for this proposition comes from Schyns, Roefs, Mulkens, & Jansen (2016), who showed that exposure to desired foods reduced subsequent intake of the same foods. Future research should explore this further by assessing if a distal presentation of chocolate cues, such as in the current study, does indeed invoke a form of sensory-specific satiety to chocolate over the course of the study. One way

that this could be achieved would be to track ratings of liking for chocolate and crisps alongside changes in consumption throughout an ABR intervention.

Results also showed that the number of days on which participants reported consuming chocolate decreased over the course of the study. Self-reported chocolate consumption was less frequent (reported on fewer days) during the week between the end of the intervention and the follow-up questionnaire than it was in the seven days prior to the first testing session. This reduction was seen across participants, independently of intervention condition. Although this measure of intake was relatively crude (days on which chocolate was eaten were counted), the finding is still intriguing. The design of Chocolate Consumption Questionnaire (CCQ) was modelled on the Timeline Follow Back (TLFB; Sobell & Sobell, 1992), a measure frequently used in alcohol research to calculate the frequency and amount of alcohol consumption (Jones et al., 2016). Given the similarities in the TLFB and CCQ, measuring the number of days on which chocolate was consumed seems simple, yet appropriate, for this study.

One explanation for the decrease in chocolate consumption may be that, because participants were aware they would be asked to report their chocolate intake, this heightened awareness led to reduced consumption via impression management (participants changed their intake to produce a more positive impression of themselves; Vartanian, 2015; Vartanian et al., 2008). This would be consistent with previous findings that simply monitoring intake of a food or drink can help in reducing intake (Robinson, Hardman, Halford, & Jones, 2015), thus providing support for the use of self-monitoring during dietary changes. Although it

is likely that this strategy is useful regardless of an individual's hedonic hunger level, it is promising to note that self-monitoring may have been beneficial for reducing chocolate consumption in this sample of participants with high hedonic hunger.

An alternative explanation for the reduction in chocolate consumption frequency could be related to being a participant in a research study. Although participants were blinded to the intervention and true aim of the study, they all experienced each stage of the study (laboratory assessments, home-based online tasks, chocolate consumption reporting, follow-up questionnaire). It could be that taking part in the study procedures, or being part of the control group acted as a pseudo-intervention itself. French and Sutton (2010) describe this as measurement reactivity and note that the process of undergoing assessments may alter measurements, such that being in a control group but taking part in a research study may influence behaviour. This is also supported by, MacNeill, Foley, Quirk and McCambridge (2016) who reported that participants enrolled in a behaviour change trial described heightened awareness of unhealthy behaviours as a result of participating in early trial procedures. This effect also appeared to be influenced by the social desirability of the behaviour in question. This is relevant for the current study because chocolate and crisps are high fat snack foods and, although participants did not report that they were actively dieting, their awareness of the study procedures may have made them conscious of the amount of unhealthy food they were consuming whilst engaged in a taste-based research study.

Limitations

The findings of this study must be treated with caution because the small sample size limits statistical power. The sample size of this study was chosen in accordance with previous work by Boyland, Randall-Smith and Jones (unpublished data). Other studies that used ABR but were not focussed on hedonic hunger, as was this study, have employed much larger sample sizes. For example, Kemps et al. (2015) tested 149 participants and Schumacher et al. (2016) tested 120 participants. The inferiority of the sample size in this study should be acknowledged as a significant limitation, and extending the sample size may allow for more confidence in the findings presented here.

This study was also limited in the analyses that could be performed and interpretations that could be made because of problems with the amount of GD time data. The proportion of eye movement data that was lost is exceptionally large. This was due mostly to equipment failure, and the issues with the laboratory equipment reoccurred several times during the course of the study. Future work should look to extend this sample and ensure a larger amount of eye movement data is collected.

Participants recruited to this study had BMI's ranging from 18.58 kg/m^2 to 42.68 kg/m^2. Initial participant recruitment focussed on only participants with overweight or obesity, but this was extended to participants without overweight or obesity to aid recruitment. This decision was made because higher levels of hedonic hunger are not unique individuals with overweight or obesity (see, for example, Ely, Howard, & Lowe, 2015) and hedonic hunger, not BMI, was a central focus of the study. However it may be possible that the mixture of weight status categories

confounded results, particularly if unmeasured motivational conflict was present in some participants. If overweight/obese-lean differences did exist in the relationship between AB and hedonic hunger, the mixture of weight statuses in the current study could have interfered with results and negated any potential intervention effects. Comparison of the AB-hedonic hunger relationship in groups of participants with and without overweight or obesity by repeating this study in separate subsamples of participants may yield different results. This should be explored in future research if the feasibility of ABR in reducing hedonic hunger and food intake were to be assessed again.

A further limitation to this study is the use of chocolate consumption frequency to assess home-based chocolate consumption. The days on which participants consumed chocolate were counted, but the amounts and type of chocolate were not accurately measured and individual differences in this could have been masked. For a hypothetical example, Participant A may have reported eating one small square (10g) of chocolate a day for 7 days, whereas Participant B may have reported eating four bars (4 x 250g) of chocolate on one day. Such inaccuracies in measurement and reporting would have skewed the data and implied that Participant A consumed more chocolate than Participant B, whereas difference in calorie intake between these participants would imply otherwise. Assessment of energy intake rather than frequency of chocolate consumption could have provided a more detailed understanding of the reduction effect observed in this study; however it should be noted that precise measurements were not

requested to limit participant burden and reduce the chance that such detailed self-monitoring would reduce consumption by itself.

This study, was exploratory in nature, and was aimed at testing the ABR intervention in a specific sample of participants with high hedonic hunger. Although the study benefits from assessing hedonic hunger pre- and post-intervention, comparison to a low hedonic hunger sample would provide more detailed information about the role level of hedonic hunger plays in attentional bias and chocolate consumption. The addition of a low hedonic hunger control group may also help to understand the finding of a cross-intervention reduction in frequency of self-reported chocolate consumption, and should be included in future research.

Strengths

A key strength of this study was the length of the ABR intervention. As discussed in Section 5.1, previous studies have often employed a single session of ABR. By extending this to five sessions over seven days this study hoped to be sufficient to identify the effects of the ABR intervention. Although none were observed, the length of this intervention confirms that even with a five-session intervention attentional bias and hedonic hunger may be particularly resistant to change.

A further strength of this study was the inclusion of home-based ABR sessions via the online computer tasks. Allowing participants to complete the tasks at their convenience may have improved compliance, which was overall acceptable-to-good. By allowing participants to complete the ABR online tasks outside of the

laboratory they were more likely to have been surrounded by their personal food cues (see Lowe et al., 2007), which could have heightened any effects of the intervention. Although no intervention effects were observed, it was still important that the current study included this as it follows the recommendations by Lowe et al. and adds data to the existing literature on ABR interventions that are in line with this guidance.

Summary and future directions

This study indicates that a brief (5 sessions-7-day), home-based ABR intervention is not an effective method of targeting hedonic hunger, attentional bias, or chocolate intake in individuals with high hedonic hunger. This may be due to a lack of positive, negative or ambivalent stimulus evaluation by participants, because hedonic hunger and attentional bias are especially resistant to change, or because of methodological issues. This study did show that frequency of self-reported chocolate consumption decreased, across both conditions during the study. This could have been an effect of self-monitoring or because of measurement reactivity. Results also showed that laboratory-assessed potato crisp consumption increased, which could have been due to a sensory-specific satiety effect acting on chocolate, but not potato crisps.

Future research should aim to expand this study by assessing the effectiveness of ABR in participants more likely to have positive, negative or ambivalent evaluations of the chocolate stimuli, such as dieters, or people who are motivated to change their chocolate consumption. As attentional bias may fluctuate over time (Field et al., 2016), more accessible retraining procedures should be

employed, such as allowing participants to complete the ABR intervention on a smartphone. This would expand upon the real-world relevance of ABR procedures and may mean that participants undertake the intervention at times or in places where they are faced with real-world food cues (e.g. when a shop or restaurant display of chocolate tempts them). Potential findings could also be further supported by more detailed assessment of home-based chocolate consumption to allow the calculation of energy intake or identification of snacking patterns. This is perhaps something that could be incorporated into a smartphone app to allow participants to record chocolate intake more accurately.

Chapter 6 - General Discussion

This chapter begins with a review of the aims of this thesis, followed by discussion of its key findings. I discuss how the studies in the thesis contribute to existing knowledge in three areas: the role of hedonic hunger during weight loss; the relationship between hedonic hunger and food cue reactivity; and understanding of hedonic hunger as a construct. Then I evaluate the strengths and limitations of these studies, and conclude by discussing the implications of these findings and making suggestions for future research.

6.1. Review of thesis aims

The rapidly rising rates of overweight and obesity over the past several decades have been attributed to a complex interplay between biological, psychological and environmental determinants of eating behaviour (Butland et al., 2007; Vandenbroeck, Goossens, & Clemens, 2007). Evidence shows that hedonic drivers of appetite are capable of overriding homeostatic signals of fullness (Harrold et al., 2012), and palatability of food is a key driver of consumption beyond homeostatic need (Yeomans et al., 2004). Coupled with an obesogenic environment that is characterised by constant and easily available palatable foods and cues to consume them (Lowe & Butryn, 2007; Swinburn et al., 2011), this has led to the suggestion that hedonic hunger (Lowe & Butryn, 2007) plays a role in weight loss and may constitute a barrier to weight loss success, although evidence that assesses this over time has previously been lacking. A key aim of this thesis was **i) to examine the relationship between hedonic hunger and BMI, and ii) the role**

that hedonic hunger may play in weight loss. These aims were addressed by Chapters 3 and 4, and are discussed in section 6.2.

Initial descriptions of hedonic hunger implied that it may be triggered by food cues, so an additional aim of this thesis was **iii) to investigate if food cue reactivity was an underlying mechanism of hedonic hunger.** This was investigated in Chapters 4 and 5, where the relationship between hedonic hunger and attentional bias (AB; as a measure of food cue reactivity) and how this may change during weight management (Chapter 4) was explored. Moreover, in response to the lack of interventions that target AB, hedonic hunger and food intake, a further aim of this thesis was **iv) to assess the feasibility of using a brief attentional bias retraining (ABR) intervention to reduce AB, hedonic hunger and food intake in those with elevated hedonic hunger** (Chapter 5). The contributions of this thesis to our understanding of the relationship between hedonic hunger and food cue reactivity are discussed in section 6.3.

A final, overarching aim of this thesis was v) to extend our existing knowledge of hedonic hunger itself and its relationship to obesity, through exploration of the aims described above. The literature review in Chapter 1, and experimental findings from Chapter 3-5, have furthered our understanding of the construct of hedonic hunger. This knowledge is synthesised, in the context of wider theories of obesity, in section 6.5.

6.2. The role of hedonic hunger in weight loss

The role of hedonic hunger in weight loss was explored in Chapters 3 and 4. Findings from these chapters showed that hedonic hunger decreases in participants undergoing a widely available open group behavioural weight management intervention (Weight Watchers). This decrease in hedonic hunger was observed as a decrease in Power of Food Scale (PFS) total score during the first 12 weeks of weight management. This finding was common to Chapters 3 and 4 and reflects previous findings by O'Neil, Theim, Boeka, Johnson and Miller-Kovach (2012) that hedonic hunger decreases during 12 weeks of weight management.

Whilst O'Neil et al. (2012) demonstrated reduced hedonic hunger following 12 weeks of a behavioural weight loss programme, their study did not compare changes in hedonic hunger and BMI between different interventions. As a result they were unable to determine if hedonic hunger reduced as a direct result of the nature of the weight loss intervention (also 12 weeks of access to Weight Watchers) or due to weight loss itself. In Chapter 3, I used data from the WRAP trial (Ahern et al., 2017a) which measured PFS total scores and BMI in the Brief Intervention (BI), 12 weeks of Weight Watchers (WW12) and 52 weeks of Weight Watchers (WW52) arms of the WRAP trial, allowing me to see if there were any intervention specific effects on BMI and hedonic hunger. Previous analysis of the WRAP trial has shown that all groups lost weight during the trial, but participants allocated to receive the Weight Watchers intervention for 12 weeks or 52 weeks lost more weight than those who were allocated to the brief intervention. In Chapter 3, I showed that on average, participants in all groups reduced their hedonic hunger, but reductions in hedonic

hunger were not specific to intervention arm. Specifically, hedonic hunger reduced between baseline and 12 weeks and remained suppressed in all intervention arms. This suggests that the Weight Watchers intervention was not the mechanism by which hedonic hunger scores were reduced, which is an inference that O'Neil et al. could not make from their study. Identifying that hedonic hunger reduction is not intervention-specific in behavioural weight loss also highlights that evidence is needed to identify the means by which hedonic hunger reductions occur, and how it remains suppressed.

It could be proposed that rather than reductions in hedonic hunger influencing weight loss, weight loss produces reductions in hedonic hunger. Rationale for this proposal comes from evidence of altered hedonic hunger following surgical weight loss intervention. A number of studies described in Section 1.5 have reported that, compared to participants with normal weight, participants with obesity or participants with obesity who are awaiting surgery, hedonic hunger is lower in participants who have undergone bariatric surgery and lost large amounts of weight (Husted & Ogden, 2014; Schultes, Ernst, Wilms, Thurnheer, & Hallschmid, 2010; Ullrich et al., 2013). However, a common criticism of these studies is that they compare hedonic hunger scores between groups of patients, rather than pre- and post-operatively within patients. One study did report reduced hedonic hunger within a group of patients (Ullrich, Ernst, Wilms, Thurnheer, & Schultes, 2013), however, the small sample size and wide variability in length of time between pre- and post-operative measures in this study means that inferences about the cause of this reduction in hedonic hunger cannot be made. This criticism

is common to other studies cited here, as they do not provide any investigation of what may cause the differences in hedonic hunger that are reported. One explanation for these changes could be due to changes in gut hormone release following surgery promoting satiety and supressing reward driven eating.

The dramatic physical changes that occur in the gut as a result of bariatric surgery alter gut hormone signalling (Goldstone et al., 2016), and it has been suggested that reduced satiety hormone signalling impacts upon reward processing in the brain. Scholtz et al. (2014) reported reduced neural responses to palatable food in reward-related areas in patients who had undergone Roux-en-Y gastric bypass surgery, which indicates altered responding in gut-brain responses to palatable foods. This has also been reflected in behavioural findings from Miras et al. (2012), who showed that, following gastric bypass surgery, participants displayed reduced appetitive reward responses (assessed by a computer task that measured effort expended to receive food) for chocolate candies, but not vegetables. Considering tentative findings that hedonic hunger reduced following bariatric surgery (Ullrich et al., 2013), it would be reasonable to suggest that it is the effect of altered gut hormone signalling, rather than weight loss per se, that causes a reduction in hedonic hunger. However, to date no studies have explicitly assessed this. Furthermore, analysis of the relationship between hedonic hunger and BMI in Chapter 3 did not indicate that weight loss predicted changes in hedonic hunger: no significant relationship between BMI and future hedonic hunger was observed. In fact, the opposite pattern of change in hedonic hunger predicting future BMI emerged, so it may be that some aspect of the initial weight loss stages, relating to

consciously monitoring one's weight and adopting new lifestyle habits and routines, is influencing hedonic hunger.

Changes to lifestyle, habits and routine in order to promote weight loss are common to participants undergoing surgical and non-surgical weight loss interventions. Successful weight loss typically requires that participants reduce consumption of high fat or high sugar foods, and consume lower fat and lower calorie foods, in addition to increasing physical activity. Non-surgical weight loss programmes, such as Weight Watchers, guide participants to do this through dietary recommendations. Following bariatric surgery, the physical restriction placed on the gut as a result of the surgical procedure also requires drastic food limitations in order to avoid unpleasant physiological symptoms (for example, dumping syndrome (Fobi, Lee, Holness, & Cabinda, 1998)). Successfully implementing such lifestyle changes conducive to weight loss likely involves goal setting, and deliberate planning and attention to eating behaviour (Adriaanse, de Ridder, & de Wit, 2009; Papies, Stroebe, & Aarts, 2009). As weight loss gets underway, the experienced benefits of losing weight (such as improved psychological well-being; Lasikiewicz, Myrissa, Hoyland, & Lawton (2014)) may become associated with the lifestyle and dietary changes that have been effortfully implemented, so that whereas palatable food may have triggered a desire response, this response becomes less frequently activated. Alternatively, whereas palatable foods and their related cues may have once activated hedonic goals, grabbing attention and guiding behaviour towards consumption, during weight loss this is in conflict with dieting goals to reduce consumption of such foods to reduce weight (Stroebe, Papies, & Aarts, 2008), so

successful dieters must overcome these hedonic responses and the temptation they pose (Appelhans, French, Pagoto, & Sherwood, 2016). Repeatedly doing this during weight loss may serve to weaken the hedonic response to palatable food and/or strengthen inhibitory responses that promote weight loss success, which may be driving the reductions in hedonic hunger during the initial stages of weight loss in Chapter 3 and 4. Future research may investigate this by establishing commonalities between surgical and non-surgical weight loss participants in goal implementation strategies and attention to food.

Heightened hedonic hunger has been proposed as a potential barrier to successful weight loss (Lowe & Butryn, 2007; Naughton, McCarthy, & McCarthy, 2015), however little research has been conducted to identify how this hypothesised barrier may relate to intervention success. Chapter 3 showed that the effectiveness of the 12-week Weight Watchers programme, compared to BI, in reducing BMI over 12 months, was reduced when participants had higher hedonic hunger than lower hedonic hunger. This implies that having high hedonic hunger at the start of a 12 week behavioural weight loss intervention is a barrier to weight loss success at 12 months that is not faced by participants with low hedonic hunger. This finding has important public health implications because 12 weeks referral to Weight Watchers is a treatment offered by NHS primary care providers (Weight Watchers, n.d.), and this finding indicates that when a person with high hedonic hunger is prescribed this treatment option, they are not going to achieve as great a BMI reduction at 12 months than someone who has low hedonic hunger.

Chapter 3 also showed a predictive relationship between hedonic hunger at 3 months and BMI at 12 months in the WRAP trial, such that early reductions in hedonic hunger are predictive of greater weight loss success. The implication of this finding was that if a participant displayed higher hedonic hunger at their 3 month visit of the WRAP trial, they would also have a higher BMI at their 12 month visit. Conversely, reduced hedonic hunger at 3 months was predictive of reduced BMI at 12 months. The evidence of initial reductions in hedonic hunger shown in Chapter 3 and 4 also imply that, whilst heightened hedonic hunger is a potential barrier to successful weight loss, it may also be modifiable. The identification of modifiable characteristics or processes that represent a vulnerability to obesity has been highlighted by Jansen, Houben and Roefs (2015) as a crucial focus for future research aimed at identifying targets for intervention in obesity. Furthermore, evidence shows that weight regain often occurs beyond 6 months after the end of weight loss interventions (Wing, 2002), so these results indicate that assessing hedonic hunger at the start of treatment and after initial weight loss may identify individuals who have not reduced their PFS score and are at risk of higher BMI/weight regain at 12 months. Taken with the findings that hedonic hunger reduces over 12 weeks of behavioural weight management, and a 12 week Weight Watchers intervention is less effective in those with higher hedonic hunger, Chapter 3 highlights the need for effective, scalable interventions that target hedonic hunger in order to improve weight loss outcomes in individuals with elevated PFS scores upon entering treatment .

A further finding from Chapter 3 was that the effect of hedonic hunger on weight loss was no longer apparent at 24 months. In the context of the WRAP trial, by the time they attended the 24 month visit all participants had been in the weight loss maintenance stage of the trial for at least 12 months. This implies that hedonic hunger reductions may be predictive of BMI in a relatively short time frame only (12 months), rather than extended time periods of 24 months. Alternatively, this finding could indicate that hedonic hunger is more influential during the initial stages of weight loss (during the first 12 months), but not during weight loss maintenance (months 12-24). During the first 12 months of weight management participants may have been making the lifestyle and behavioural changes (for example, development of personal strategies to adhere to their diet; Papies, 2012) necessary to lose weight, and their dieting goals may have become established. Beyond this point, successful dieters may have overcome their hedonic hunger sufficiently that it no longer represented a barrier to successful weight management. The maintained suppression of PFS scores between 3 and 24 months of the WRAP trial would support this, permitting the suggestion that once reduced, hedonic hunger was not predictive of future BMI because participants no longer experienced taxing levels of hedonic hunger. An alternative explanation for this may be that successful weight loss bolstered inhibitory control processes, which in turn reduced hedonic hunger or the effect of hedonic hunger on BMI to the point that it was no longer a predictor of future BMI. However, the observational nature of the data in Chapter 3 make it impossible to test if either of these explanations are correct, so future work that tests the effects of potential interventions for hedonic hunger may be able to clarify this.

6.3. The relationship between hedonic hunger and food cue reactivity

Chapters 4 and 5 explored the relationship between hedonic hunger and food cue reactivity by measuring attentional bias (AB). AB was chosen as a measure of food cue reactivity based on previous work that has highlighted its relevance to measuring the appetitive motivations which can be reflected in the way a cue captures and holds attention (Field & Cox, 2008; Field et al., 2016). AB is also widely used to assess food cue reactivity in appetite research (Doolan, Breslin, Hanna, & Gallagher, 2014; Hendrikse et al., 2015b; Werthmann, Jansen, et al., 2014). However, it should be acknowledged that AB is not the only way of measuring this. Other methods for assessing food cue reactivity are discussed in section 1.8.4.1 of this thesis but, briefly, may include assessment of approach tendencies to food stimuli (e.g. Havermans, Giesen, Houben, & Jansen, 2011; Kemps, Tiggemann, Martin, & Elliott, 2013), desire to eat and salivary response following food cue exposure (e.g. Ferriday & Brunstrom, 2011) or assessment of neural responses to food images (e.g. Stoeckel et al., 2008), among others. As this thesis used AB as an analogue of food cue reactivity (Field et al., 2016), discussion of the relationship between hedonic hunger and food cue reactivity is based on findings from assessment of AB only.

Despite theoretical suggestions that hedonic hunger may be triggered by external food cues, or represent a heightened sensitivity to food cues (Lowe & Butryn, 2007), findings from this thesis do not clearly support this when food cue reactivity is assessed by AB. Baseline measurements of hedonic hunger and AB in Chapters 4 and 5 indicate that there is no cross-sectional relationship between these two constructs: PFS total score was not correlated with indexes of AB in either study.

An explanation for this may be related to the transient nature of AB that has recently been described by Field et al. (2016). Field et al. have proposed that AB is more state-like than trait-like and is influenced by current motivational states and stimulus evaluation. When baseline measures of AB were collected in Chapters 4 and 5, participants were not actively dieting, had not fasted for an excessively long period of time and had not been recently exposed to food cues. Nijs, Muris, Euser, and Franken (2010) found differences in AB depending on fasting state in their participants, and Lattimore and Mead (2015) showed that AB was greater in participants who had been exposed to food cues (although this was moderated by impulsivity), however such motivational states did not apply to participants at baseline assessments in Chapters 4 and 5. Therefore, participants may not have been in an appropriate motivational state for display or measure of AB when they attended baseline assessments.

An additional explanation for the lack of cross-sectional relationship between AB and hedonic hunger relates to the way participants may have evaluated the stimuli used in the visual probe tasks. Field et al. (2016) proposed that AB occurs when attention is captured by cues as a result of cue evaluation. Cues may be evaluated in a positive, negative or ambivalent (positive and negative) manner. An appetitive cue, such as the sight of a favourite food, may be evaluated positively because it is attractive. An unappealing cue, such as a disliked food, may be evaluated negatively because they are unpleasant. As such, positive and negative evaluations result in attentional capture because they provoke physiological arousal. Ambivalent evaluations cause attentional capture because the positive evaluation of

a food cue may occur in response to the perceived palatability of the food the cue represents, whilst negative evaluation may also occur because consumption of the palatable food is not in line with dieting rules and therefore threatens weight management goals. These contradictory evaluations create motivational conflict, which in turn captures attention (Field et al., 2016). In Chapter 5 participants were assessed as being not actively dieting (although other weight and food-related motivations may have been present), so the stimuli in the visual probe task may not have produced sufficient motivational conflict to produce AB. An absence of motivational conflict would not have triggered AB, so this could explain why no relationships between hedonic hunger and AB were observed: AB was not present.

Christiansen, Mansfield, Duckworth, Field and Jones (2015) highlighted that the use of personalised stimuli heightens the internal reliability of the visual probe task. The visual probe tasks used in Chapters 4 and 5 did not use personalised stimuli, and food stimuli were selected based on those used in previous literature (Chapter 4) or to represent chocolate and chocolate items (Chapter 5). Furthermore, participants' liking of the foods depicted in the task stimuli was not assessed, so it is possible that either the images or the foods they represented were not attractive enough to participants to evoke a positive evaluation (Field et al., 2016). Alternatively, in Chapter 4 the mixture of foods depicted in stimuli may have contained only a small number of foods that were positively (or negatively, if a disliked food was presented) evaluated, so the arousal triggered by this was masked by limited evaluation of other stimuli, resulting in inconsistent levels of AB between participants that was not associated with hedonic hunger. Using personalised stimuli

and assessing participants' liking of foods and the image stimuli may have been more sensitive to individual participants' stimulus evaluations and could have resulted in measurable AB.

Although no cross-sectional relationship was observed, a relationship between hedonic hunger and AB emerged when changes in hedonic hunger and AB to high calorie foods was assessed in Chapter 4. Results showed that reduction in PFS total score was associated with reduction in AB to high calorie food cues in participants with high hedonic hunger at baseline, indicating that during the course of weight loss these participants reduced their hedonic hunger and reactivity to high calorie food cues (as assessed by AB). This finding can also be explained in terms of AB being reflective of motivational state and triggered by stimulus evaluations, as proposed by Field et al. (2016). The reductions in AB to high calorie foods shown in Chapter 4 represent a change that occurred whilst participants were engaged in weight loss. The significant decrease in BMI shown in Chapter 4 indicates that, overall, weight loss was achieved. When AB and hedonic hunger were assessed following weight loss, participants were returning to the laboratory having just completed 12 weeks of dieting, so their motivational state may have reflected this. Successful weight loss may have produced a motivational state that was characterised by avoidance of high calorie foods that are not conducive to weight loss, and as these foods may have been excluded to achieve weight loss, attention was less readily captured by them, resulting in reduced AB scores. It is not possible to conclude from these data if these changes were a result of, or contributor to, the reduction in hedonic hunger that was also observed, however greater reductions in

hedonic hunger were associated with greater AB reductions. This implies that while a relationship between reduced AB and reduced hedonic hunger is apparent, direction of causality or the influence of unmeasured factors within the relationship cannot be determined.

As Chapter 3 indicated that reducing hedonic hunger may have a beneficial effect on future BMI, and Chapter 4 indicated that reductions in hedonic hunger were associated with reductions in AB to high calorie foods in those with high hedonic hunger, Chapter 5 of this thesis tested the feasibility of an ABR intervention for reducing AB, food intake and hedonic hunger in women with elevated hedonic hunger. While the intervention itself proved feasible, no statistically significant effects of ABR on AB, food intake or hedonic hunger were observed, implying that ABR is not an effective intervention for these purposes. This was in contrast to Boutelle, Monreal, Strongand Amir (2016), who showed that an 8-week ABR intervention reduced scores on the three subscales of the PFS (food present, food available and food tasted; described in Section 2.4.1). However, the study by Boutelle et al. had many limitations, which would result in its findings being viewed with caution. They only reported data from 9 participants and would need to include a much larger sample size in order to have confidence that they have found a true effect. Furthermore, they did not compare their findings to a control group, and no rationale was provided for using PFS subscales rather than the PFS total score as a measure of hedonic hunger. Likewise, the sample size in Chapter 5 was insufficient to provide the analyses with adequate statistical power, so effects may have gone undetected.

A further explanation for the lack of observed effects of ABR on hedonic hunger, AB and food intake relates to the characteristics of the participants studied. As Chapter 5 was a feasibility study, participants were not selected to fully represent a potential target population for the intervention. While participants with high hedonic hunger were recruited for the study, no criteria relating to participants having a desire to reduce chocolate consumption, AB or hedonic hunger were applied to participant recruitment. In line with proposals from Field et al. (2016) discussed above, the stimuli used in the task may not have generated motivational conflict to capture attention sufficiently because participants in this study were not actively dieting and self-identified as people who liked and regularly ate chocolate.

Jones, Hardman, Lawrence and Field (2017) recently reviewed cognitive bias modification as a potential intervention for obesity and noted that many published studies did not test interventions on proposed target populations, as we did Chapter 5. As such, Jones et al. (2017) recommend that future interventions should be tested on intended populations, as not doing so may result in testing interventions of samples of participants who are not receptive to the intervention effects. This may apply to Chapter 5, so re-testing the intervention in women with high hedonic hunger who are motivated to make dietary changes may yield more positive results.

Furthermore, the short intervention time (1 week) in the study reported in Chapter 5 may not have represented enough time for stimulus evaluations to change sufficiently to change AB. Although the study reported in Chapter 5 was primarily a feasibility study, the lack of significant effects of the ABR intervention on AB, hedonic hunger and food intake could be attributed to the length of the

intervention. The intervention in Chapter 5 was one week of ABR, whereas longer interventions have been shown to be effective. For example, Kemps, Tiggemann and Elford (2015) have reported reduced AB following an ABR intervention that took place over 5 weeks. More recently, Boutelle, Monreal, Strong and Amir (2016) reported on a small-scale ABR trial in adults who binge eat. Boutelle et al. (2016) used ABR and psychoeducational leaflets as an 8-week intervention in 9 participants with binge eating. Results showed an increase in AB and decrease in PFS subscale scores, but hedonic hunger via the PFS total score was not reported. Furthermore, Boutelle et al. (2016) do not speculate on the specific mechanism through which these changes occur. Despite their methodological limitations, these two studies are in contrast to Chapter 5 in their intervention length and imply that, as AB is resistant to change (Hardman et al., 2013), longer interventions may be required for ABR to achieve its maximum effectiveness.

Alternatively, the study reported in Chapter 5 was likely too small to detect any statistically significant effects of the intervention on outcome measures, owing to the small sample size and sizeable amount of missing data. The primary aims of this study were to assess the feasibility of the ABR intervention, so the study was not sufficiently powered for significance testing. Now that the feasibility of the ABR intervention has been confirmed, future work is needed to extend the participant sample to sufficiently power significance testing.

It should be considered that as food cue reactivity can manifest in different ways other than AB, such as approach biases for food (e.g. Havermans et al., 2011; Kemps et al., 2013) or increased physiological responding (e.g. Ferriday & Brunstrom, 2011),

different methods of assessing food cue reactivity may be capturing different aspects of it. For example, while AB assesses attention allocation to cues, salivary responding may be a secondary consequence of this as food cues need to be attended to in order for them to be perceived and interpreted in a way that provokes increased salivary responses. The reason for a lack of effect of ABR on food cue reactivity measured by AB, or hedonic hunger, could be because AB is not the way hedonic hunger manifests behaviourally, and other aspects of food cue reactivity may be more reflective of hedonic hunger.

The findings of this thesis should be considered as indicating that while the relationship between hedonic hunger and AB is specific to changes in hedonic hunger and AB to high calorie foods during weight loss, the relationship between hedonic hunger and the broader concept of food cue reactivity is still partially unclear, although it is theoretically plausible (Lowe & Butryn, 2007). Chapter 5 showed no relationship between changes and AB and hedonic hunger. This may indicate that the within-participant relationships between changes in hedonic hunger and AB changes from Chapter 4 does not tell us that AB changes are a manifestation of hedonic hunger changes. Rather, the within-participant changes in AB and hedonic hunger could have been reflective of changes to an underlying mechanism. Therefore, this provides little support for the suggestion that changing AB will reduce chocolate consumption in individuals with high hedonic hunger.

6.4. Extended understanding of hedonic hunger

The findings of this thesis have also extended our understanding of the short-term stability of hedonic hunger. Witt, Raggio, Butryn and Lowe (2014) reported that hedonic hunger is stable over the course of a day, following a 4-hour fast. The current thesis extended these findings in two ways. The analysis of the effect of fasting status on baseline PFS scores in the WRAP trial in Section 2.3.9 indicated that an overnight fast of at least 12 hours did not impact hedonic hunger scores, although this analysis was conducted *a posteriori* and is based on inferences about fasting status from visit notes. This finding is important because the drivers of homeostatic and hedonic hunger are different, so it is important to ensure that the PFS is indeed measuring hedonic hunger, not homeostatic hunger. Lowe and Butryn (2007) distinguish between homeostatic and hedonic hunger, explaining that homeostatic hunger occurs in response to prolonged energy deprivation and the body's need to intake calories. Lowe and Butryn (2007) state that the palatability of a food is unlikely to influence homeostatic hunger, whereas hedonic hunger is likely to occur in the absence of homeostatic energy need, and because the body's energy need is not as strong, palatability and the rewarding value of food become more salient. However, whereas Lowe and Butryn (2007) caution that "hunger" experienced after a 12-hour fast must be homeostatic hunger, the findings of Witt et al. (2014), and analysis of fasting status and PFS scores in the WRAP sample (Section 2.3.9), would imply that the PFS still detects hedonic hunger after extended fasting, thus supporting the validity of the PFS as an assessment tool for hedonic hunger.

Regarding the longer term stability of hedonic hunger, Lowe et al. (2009) demonstrated that hedonic hunger had adequate retest reliability in undergraduate students after 4 months. The current thesis adds to this in two ways. Chapter 3 showed that although hedonic hunger decreased during the first 3 months of weight management and remained suppressed over 2 years, hedonic hunger at each time point of the WRAP trial significantly predicted hedonic hunger at the subsequent time point. Chapter 5 showed that hedonic hunger is resistant to change following a 1-week ABR intervention. These findings indicate that either hedonic hunger is trait-like and is relatively stable over time, or, if hedonic hunger as measured by the PFS is reflective of an underlying mechanism related to appetitive motivation, this mechanism itself is stable.

While the ABR intervention in Chapter 5 did not reduce laboratory food consumption, a surprising finding from that study was that the self-reported frequency of chocolate consumption (defined as number of days on which chocolate was eaten) reduced in the 7 days following the intervention, compared to the 7 days preceding it. This finding was not unique to the ABR intervention, as it was also seen in the control condition. This implies that while ABR may not be an effective means of reducing food intake in women with high hedonic hunger, self-monitoring may achieve this. Participants in both conditions of the ABR intervention were required to report their chocolate consumption throughout the study. It could be that drawing participants' attention to their chocolate consumption by requiring them to report it acted as an intervention in itself, resulting in a reduced frequency of chocolate consumption. This finding requires further testing to support it because

the measure of self-reported chocolate consumption was crude and subjective. Different participants may have eaten drastically different volumes of chocolate on a given day, but this would be logged as a day on which chocolate was consumed for both. Furthermore the sample of participants in this study all reported elevated hedonic hunger, so a low hedonic hunger control group is needed for comparison to determine if the same effects would be seen in participants who do not score highly on the PFS. Nonetheless, this finding is intriguing as it suggests that future work should investigate if self-monitoring may be an effective means of reducing chocolate intake in women with high hedonic hunger.

As is described above, Chapter 3 showed that reductions in hedonic hunger between baseline and 3 months are not specific to the Weight Watchers interventions employed in the WRAP trial as they were seen across all interventions. A commonality of the BI, WW12 and WW52 interventions in the WRAP trial is that they each involved consciously managing diet and weight in order to achieve weight loss. From this it can be proposed that conscious self-monitoring may be involved in reductions to hedonic hunger; however these data are observational so this can only be speculated. More research to identify what drives change in hedonic hunger during weight loss is required.

In contrast to previous literature, Chapter 5 did not find an association between hedonic hunger and food intake. Appelhans et al. (2011), Ely, Howard and Lowe (2015) and Stok et al. (2014) have previously shown that higher hedonic hunger is associated with greater food intake within the laboratory (Appelhans et al., 2011; Ely et al., 2015) and in the form of general snacking (Stok et al., 2014). These

findings are not reflected by Chapter 5. This could be because participants in Chapter 5 all reported heightened hedonic hunger, so there was insufficient variability in PFS scores for an association to emerge. An alternative explanation may be that whilst greater hedonic hunger represents an increased motivation for palatable foods, something else intervenes to influence actual consumption of such foods. A likely candidate is inhibitory control, which may act to prevent food consumption in order to maintain an internal goal (such as dieting; Papies, 2012). This will be discussed within the wider context of hedonic hunger's place in broader theories of obesity in section 6.5.

Previous research has indicated an inconsistent relationship between hedonic hunger (PFS total score) and BMI. Cappelleri et al. (2009) reported an association between hedonic hunger and obesity, and Thomas et al. (2013) indicated that hedonic hunger is higher in participants they classified as "obese prone". Furthermore, Cushing et al. (2014) indicated that hedonic hunger fluctuated in line with BMI over 2 years in 16 adolescents who underwent bariatric surgery. Conversely, Mitchell, Cushing, and Amaro (2016), Witt, Raggio, Butrynand Lowe (2014), and Appelhans et al. (2011) report no significant associations between hedonic hunger and BMI. In line with contradictory findings, Chapter 3 of this thesis showed a small, positive correlation between baseline PFS total score and baseline BMI, which indicated that greater hedonic hunger was associated with higher BMI; Chapter 4 showed no such association. In addition to this, a number of the participants with high hedonic hunger in Chapter 5 were normal weight, implying that high hedonic hunger is not unique individuals with overweight or obesity. This

suggests that while hedonic hunger may be linked to BMI, other factors, such as inhibitory control, may influence how hedonic hunger is manifested behaviourally to influence BMI. If the relationship between hedonic hunger and BMI is not direct, Chapter 4 may have been underpowered to detect this.

6.5. Hedonic hunger in the wider context of obesity theory

In order to fully demonstrate the contribution of this thesis to our understanding of hedonic hunger and its relationship with food cue reactivity and BMI during weight management, it is necessary to consider the findings discussed above within the wider context of current dual process theories of obesity. An overview of dual process theories of obesity will be presented, followed by a proposal for how hedonic hunger can be incorporated into these theories. Following this, the concept of hedonic hunger as a construct in itself will be discussed. This section will conclude with a theoretical proposal for the suggested underlying mechanism of hedonic hunger.

Dual process theories of obesity (Hofmann, Friese, & Strack, 2009; Strack & Deutsch, 2004) posit that impulsive and reflective processes interact to determine behaviour. Impulsive processes are activated automatically by bottom-up processing of stimuli (Strack & Deutsch, 2004) and result from repeated associations between a cue and an outcome. With regards to eating behaviour, impulsive processes result from a conditioned association between a cue, such as the presence or smell of food, and the rewarding outcomes of consuming the food (pleasure). This is reflective of Incentive Salience Theory (discussed in Section 1.8.2), which predicts

that the rewarding dopaminergic response to a substance (such as a palatable food) becomes sensitised following repeated exposure to the substance. Cues that signify the substance (such as the smell of cookies) obtain the rewarding properties of the consequence (enjoying eating the cookies) through repeated pairings that result in the cue being able to trigger the conditioned rewarding response, capture attention and influence behaviour (Berridge, Ho, Richard, & DiFeliceantonio, 2010; Berridge & Robinson, 2003; Robinson & Berridge, 1993). These impulsive processes occur automatically, often overriding behavioural intentions, to produce counter-intentional actions (Naughton et al., 2015). Jones et al. (2017, pp.2) describe this as an automatic process which may prompt people to "eat without thinking".

Complimentary to impulsive processes are reflective processes (Hofmann et al., 2009; Strack & Deutsch, 2004) which are self-regulatory processes that work to inhibit pre-potent impulsive responses. Jones et al. (2017) aptly describe these processes as being top down, as they are akin to executive functions that control working memory, set shifting and response inhibition (Miyake & Friedman, 2012). Dual process models of obesity (Hofmann et al., 2009; Strack & Deutsch, 2004) propose that obesity results from a disparity between the actions of impulsive and reflective processes, such that one may override the other. In the context of dieting, a strong desire or motivation for palatable food when presented with a sign of its availability (such as the smell of cookies) may override self-regulatory processes (such as resisting cookies because they are incongruent with weight loss goals) to drive attention and behaviour towards the palatable food (eating the cookies).

My example of the cookies described above can be used to demonstrate how hedonic hunger conforms to dual process models of obesity, and why not all people who experience elevated hedonic hunger may become obese. Hedonic hunger may represent bottom up impulsive processes in the dual process model. Individuals with heightened hedonic hunger may experience a greater sensitivity to the rewarding properties of food, which manifests as a strengthening of impulsive processes: people with higher hedonic hunger may be more tempted by the cookies because they have a greater sensitivity to their rewarding properties. Repeated cookie consumption strengthens the association between the smell of cookies and their pleasant taste. However, when attempting to lose weight, reflective processes must override the impulsive processes, so inhibitory control abilities are needed to regulate the motivation for cookies in order to adhere to a diet to achieve weight loss. In other words, the strengthened desire for cookies must be overcome because cookies are high in fat and sugar, thus making them not conducive to weight loss. Those who achieve this may succeed in losing weight and, over time, repeated exercising of inhibitory control to resist the cookies may result in a decrease in the strength of the bottom up influence (hedonic hunger) on behaviour. This could be behind the finding from Chapter 3 that showed that while baseline hedonic hunger did not predict weight outcomes, reduced hedonic hunger at 3 months predicted future BMI at 12 months. In this context, this may indicate that reductions in hedonic hunger may result from strengthening of reflective processes during weight loss, so they are strong enough to override impulsive processes. When reflective self-regulation abilities are lacking, impulsive processes are more likely to "win" and guide attention and behaviour.

In terms of hedonic hunger, Naughton et al. (2015) proposed that hedonic hunger overwhelms behavioural intentions (reflective processes) to resist palatable food. Jensen, Duraccio, Carbine, Barnett and Kirwan (2016) have previously shown that greater hedonic hunger in adolescents is associated with reduced neural activation in areas of the brain that are associated with inhibitory control (dorsolateral prefrontal cortex, medial prefrontal cortex, right inferior parietal lobule) in response to viewing images of high-energy foods. This implies that, when presented with food cues, insufficient activation of reflective processes occurs in those with higher hedonic hunger.

Conversely, some people may have high hedonic hunger and strong self-regulatory abilities, so that they experience the drive for palatable food but inhibit their response to eat it. This is supported by Price, Higgs and Lee (2015), who showed that heightened responsiveness to the rewarding value of food predicted BMI only when impulsivity was also high. This proposal suggests that further study of how heightened hedonic hunger may be related to inhibitory control abilities is needed, and inhibitory control training may be more effective than ABR as a means of strengthening self-regulation abilities for those with high hedonic hunger. Chen, Veling, Dijksterhuis and Holland (2016) theorise that inhibitory control training effectively changes stimulus evaluations by repeatedly pairing cues with the requirement to inhibit a response, and this devaluation of appetitive cues reduces how likely an individual is to respond to them. Future research should consider utilising inhibitory control training to investigate if such stimulus devaluations may

help those with high hedonic hunger to resist eating in response to drives for palatable foods.

This thesis also adds to our understanding of hedonic hunger as a construct in itself. By showing that hedonic hunger is relatively constant over time I have provided a rationale for the proposal that the underlying mechanism of hedonic hunger, whatever that may be, is stable. Several recent studies (Bouhlal, McBride, Trivedi, Agurs-Collins, & Persky, 2017; Price et al., 2015; Vainik, Neseliler, Konstabel, Fellows, & Dagher, 2015) have aligned hedonic hunger with other validated measures of eating behaviour to suggest that the PFS and such scales measure a common construct, rather hedonic hunger representing an underlying mechanism. Vainik et al. (2015) suggest this common construct is "uncontrolled eating"; Price et al. (2015) name this "food reward responsivity"; Bouhlal et al. (2017) refer to this as "drive to eat" (although it should be noted that Bouhlal et al. only included PFS subscales, not total score, in their analyses so their assertion that they assessed "hedonic hunger" is interpreted with care).

However, these findings are in contrast to Lowe et al. (2009) who suggest that the PFS predicted variance in measures of disinhibition and external eating, implying that the PFS taps a construct that is broader than what these scales measure. Furthermore, as Price et al. comment, items on the PFS and measures of disinhibition and external eating relate to eating in response to external cues and enjoyment of eating, not just uncontrolled eating, or reward-based eating behaviour. Therefore, it is possible that hedonic hunger represents a precursor to impulsive processes that influence eating behaviour as, in order for eating to occur

in response to cues, the rewarding value of the food needs to be established in order for cues to gain their salience. As such, a generalised sensitivity to the rewarding value of food may be an underlying mechanism of hedonic hunger, and poor regulation of this results in overeating and constitutes a barrier to successful weight loss. In order to test this, research is needed that assesses general and food-specific reward sensitivity alongside hedonic hunger in order to see whether reward sensitivity is predictive of PFS scores. If so, future weight loss interventions may use the PFS as a screening tool to identify those with heightened underlying reward sensitivity to food and develop interventions to target this by reducing the salience of cues whilst simultaneously strengthening reflective processes, perhaps via inhibitory control.

6.6. Strengths and Limitations

6.6.1. Sample Size

A key strength of this thesis is the size of the participant sample and length of assessment period in Chapter 3. To my knowledge, Chapter 3 represents the largest longitudinal study of hedonic hunger and BMI during behavioural weight loss to date. There have been previous studies that have measured hedonic hunger over time during different types of weight loss interventions, such as O'Neil et al. (2012; commercial behavioural weight loss), Theim et al. (2013; partial meal replacement weight loss) , and Ullrich et al. (2013; bariatric surgery weight loss), but none of these studies are of the same scale as the study reported in Chapter 3. Participant samples in previous studies have been much smaller (47 in Ullrich et al; 111 in Theim

et al.; 111 in O'Neil et al.) and assessments were carried out over shorter time frames/interventions (approximately 15 months after surgery in Ullrich et al.; 15 week intervention in Theim et al.; 12 week intervention in O'Neil et al.). An exception is Cushing et al. (2014), who assessed hedonic hunger and BMI over 24 months in adolescents undergoing bariatric surgery, however this study was based on 16 participants, a drastically smaller sample than Chapter 3.

Sample sizes in Chapters 4 and 5 were not optimal. Chapter 4 studied 57 participants over a 12 week Weight Watchers intervention. This sample size is smaller than O'Neil et al. (2012), who employed the same weight loss intervention in 111 participants, and also smaller than in other AB studies. For example, Kemps et al. (2015) showed reduced chocolate consumption and AB in a sample of 149 female undergraduate students, a much larger sample than in Chapters 4 and 5. Sample size in Chapter 4 was constrained by a lower than expected participant enrolment rate from the Liverpool site of the WRAP trial, and so recruitment criteria were extended (Section 2.7). Difficulties with recruitment may have caused this study to be underpowered to detect effects, although it should be noted that results showed a decrease in PFS scores during weight management consistent with O'Neil et al. Nonetheless, the small samples sizes of these studies may have increased the chance of type 2 errors (false negative). Jones, Hardman, Lawrence and Field (2017) comment that undersized samples and weak statistical power is common within the ABR (and related) literature and studies often require as many as hundreds more participants than are recruited to adequately power such intervention studies. In

light of this, the sample sizes in Chapters 4 and 5 are inadequate and should be greatly extended in future work.

Chapter 5 was a small-scale feasibility study that aimed to determine the practicability of using multi-session home-based ABR to reduce attentional bias, hedonic hunger and chocolate consumption in non-dieting individuals with elevated levels of hedonic hunger. Although this study arguably did achieve its feasibility aims (section 5.1.7), the sample size of this study limited statistical power for significance testing. As such, a larger sample is needed to draw additional conclusions about the effects of ABR on hedonic hunger, AB and food consumption in participants with elevated hedonic hunger. However, examination of effects suggests that while this ABR intervention may be able to modify AB in a larger trial, it is unlikely to have a meaningful impact on hedonic hunger or food consumption.

6.6.2. Missing Data

The attrition rate in Chapter 3 (from participants either withdrawing from the WRAP trial or not providing full data at all time points) resulted in a reduced amount of data being available (n=594) for analyses of hedonic hunger and BMI between baseline and 24 months. This level of attrition is to be expected in a weight management trial of this length and this is still the largest sample of complete data to date; however the implication of this for this thesis was that the study described in Chapter 3 was underpowered to perform more complex analyses than those which are reported. The autoregressive cross-lagged model reported in Section 3.3.4 could not be repeated for each intervention arm separately as the number of participants in the BI intervention was not sufficient to power such an analysis.

Arguably, however, this would not have been appropriate due to the lack of interaction between hedonic hunger and intervention type reported in Section 3.3.2

An additional implication of missing data in the study reported in Chapter 3 relates to the analysis strategy used. In their analysis of the main WRAP trial outcomes, Ahern et al. (2017) report findings from analyses that used a completers only approach, baseline observation carried forward (BOCF), last observation carried forward (LOCF) and missing at random (MAR) analysis strategies to impute missing data. Imputation of missing data is not appropriate for calculating bias corrected bootstrap confidence intervals in the analyses described in Chapter 3, so data imputation could not be performed. This reflects a limitation of the current thesis as the completers only analysis approach adopted in Chapter 3 does not conform to the approaches used to analyse the main WRAP trial data (Ahern et al., 2017) and it cannot be known if a BOFC, LOCF or MAR analysis would have yielded different results. Ahern et al. (2017) do not report any differences in the pattern of significance shown in their results when completers only, BOCF, LOCF or MAR strategies were used, however we cannot know if this would be the same for these analyses.

Chapters 4 and 5 were also subject to sizeable amounts of missing data. In Chapter 4, eye movement data was missing for 16 of 57 participants; in Chapter 5 eye movement data was missing for 15 of 40 participants. The studies described in Chapters 4 and 5 were run in the same laboratory, using the same eye-tracking equipment. The reason for the amount of missing data was largely due to poor/unsuccessful calibration of the eye-tracker (Chapter 4) and equipment failure

(Chapters 4 and 5). Unfortunately the eye-tracker developed a serious fault that recurred intermittently during the time the data for Chapter 5 was being collected, resulting in large amounts of data loss due to recording failures. This severely limited the data that could be used to calculate GD AB scores in these studies, and resulted in the related analyses being underpowered. As such, the findings from Chapter 4 and 5 are interpreted with caution.

6.6.3. Generalisability

A further consideration related to participant samples used in this thesis is the number of male participants included in this work. The disproportionate inclusion of female participants in this thesis limits the generalisability of the findings to male populations. Chapter 3 included approximately twice as many female as male participants, although this was reflective of the wider WRAP trial sample and actually represented a higher male to female enrolment ratio than is typically seen in similar trials (Ahern et al., 2016). A small number of male participants were enrolled in the study described in Chapter 4, although the study was open to both sexes. The small number of male participants volunteering for the study described in Chapter 4 may be reflective of the reduced likelihood of men to enrol in the WRAP trial (Ahern et al., 2016). This could also be attributed to the intervention offered by the study in Chapter 4 (12 weeks access to Weight Watchers), which may have been less appealing to male participants as they may perceive commercial weight management (such as Weight Watchers) as being more feminine and aimed at women (Robertson et al., 2014). As a result of the findings from Chapters 3 and 4 coming from a mostly female sample, the study reported in Chapter 5 excluded

male participants for consistency with the previous chapters and existing ABR literature.

The result of this is that the findings of this thesis should be generalised to men with some caution as men were underrepresented in the participant sample. However, it should be noted that the analyses conducted in Chapter 3 controlled for gender, and Ribeiro et al. (2015) did not find any gender differences in PFS scores in their Portuguese PFS validation study, so it is likely that the findings described in this thesis are somewhat generalisable to male samples. Nonetheless, in order to confirm this, future work should endeavour to include equal numbers of male and female participants in related studies.

6.6.4. Study design and length of follow up

In this thesis I have studied hedonic hunger at multiple time intervals during weight loss and during an ABR intervention. Chapter 3 measured hedonic hunger at baseline, 3, 12 and 24 months of the WRAP trial; Chapter 4 measured hedonic hunger over 12 weeks; and Chapter 5 measured hedonic hunger over 1 week.

The fact that Chapter 3 was conducted as part of the WRAP trial represents a strength of this thesis. The WRAP trial was a Randomised Control Trial (RCT), and RCTs are regarded as a crucial element and the "gold standard" of clinical research (Stang, 2011). This is due to the random allocation of participants to interventions, which ensures that participant groups are comparable, as the effects of potential confounding participant characteristics or unknown factors are thought to be minimised by their random distribution across treatment groups. This also ensured

that allocation of participants with differing hedonic hunger scores and demographic characteristics that could have influenced weight loss was comparable across intervention arms. Therefore, the nature of the RCT design minimises the likelihood that the findings of Chapter 3 were influenced by non-random factors within the participant group.

An additional strength of this thesis is how the use of varied intervention lengths in Chapters 4 and 5 permits a more detailed exploration of changes in hedonic hunger scores, BMI and AB as potential behavioural correlates of hedonic hunger. Chapter 1 described a number of studies that have explored the relationship between hedonic hunger, BMI and/or behavioural correlates of hedonic hunger (Section 1.4). Several of the studies described in Section 1.4 were cross-sectional or observational in design. For example, Thomas et al. (2013) showed that hedonic hunger was higher in those classified as "obese prone" in a single-session study; Yoshikawa, Tanaka, Ishii, and Watanabe (2014) report observational findings that increased hedonic hunger is associated with more intense magnetoencephalography (MEG) responses in the insular cortex when viewing food images; Stok et al. (2014) showed a cross-sectional relationship between PFS scores and snack consumption in adolescents. While these studies, and others described in Section 1.4, help to elucidate the behavioural correlates of hedonic hunger, the current thesis extended investigations of a potential correlate of hedonic hunger by assessing the relationship between PFS scores and AB (Chapters 4 and 5) and BMI (Chapter 4) over time. In doing so, this thesis identified that rather than baseline hedonic hunger being associated with a potential behavioural correlate (AB),

changes in AB to high calorie foods and changes in hedonic hunger were related. This highlights that when exploring the relationships between hedonic hunger and weight-related constructs, future research should consider examining changes over time, not just cross-sectional associations.

6.6.5. Choice of weight management intervention

The Weight Watchers intervention utilised in Chapters 3 and 4 provided participants with vouchers to attend weekly weight loss group sessions and unrestricted access to the Weight Watchers e-Source during the intervention time Section 2.2. My intention when beginning this thesis was to include intervention engagement in weight loss-related analyses to explore if the number of weight loss group sessions a participant attended, or the amount of time they spent using the e-Source, mediated any effect of the intervention on weight loss and/or changes in hedonic hunger. Frequency of attendance at weight loss group sessions during weight loss interventions has been shown to influence weight loss outcomes. In behavioural weight loss interventions similar to those employed in Chapter 3 and 4, the number of weight loss groups sessions attended has been shown to predict weight loss (Finley et al., 2007; Stubbs, Morris, Pallister, Horgan, & Lavin, 2015). Furthermore, increased engagement with online weight loss resources (considered as website visits, weight and dietary log completion) during web-based commercial weight loss interventions has been shown to predict greater weight loss (Hwang, Ning, Trickey, & Sciamanna, 2013; Johnson & Wardle, 2011; Postrach et al., 2013). Unfortunately, an error within the main Weight Watchers UK administrative computer system resulted in data for the number of Weight Watchers meetings

attended and e-Source usage not being accurately recorded for participants in Chapter 3 and 4. Consequently, I was not able to access data regarding intervention usage for this thesis. The exclusion of these data from this thesis means that I was unable to explore how differences in intervention use may have influenced weight loss and, potentially, changes in hedonic hunger (Chapters 3 and 4) and attentional bias (Chapter 4). It is possible that participants who were more engaged with the intervention may have lost more weight than those that were not, and this difference in weight loss may have been reflected in differences in the relationship between BMI and hedonic hunger, but it is not possible to confirm this within the current thesis. Future work should attempt to address this methodological issue by employing a subsidiary method for attaining intervention usage in case such administrative errors were to recur, especially for studies of this size. With hindsight, I would have also requested participants in Chapter 4 to report or log the dates of the Weight Watcher meeting attendance or taken copies of their meeting record cards (Section 2.3.1) to obtain, at least, a self-reported assessment of meeting attendance to gauge intervention engagement.

Despite issues with missing intervention usage data, the use of Weight Watchers as the open group behavioural weight management intervention in Chapters 3 and 4 is a further strength of this thesis. Weight Watchers is one of the most common forms of weight loss used globally (Weight Watchers, 2016) and in primary care in the UK (National Institute of Health and Clinical Excellence, 2014). Within the UK there are over 6000 Weight Watchers meetings (Weight Watchers, 2017) and Weight Watchers and the NHS operate a referral scheme whereby health providers

can refer patients to Weight Watchers as part of primary care (Weight Watchers, n.d.). Moreover, as discussed in Chapter 1, there is good evidence to support its effectiveness as a weight loss intervention (Section 1.2.3.2). These points highlight the generalisability of the results in Chapter 3 and 4, as the findings are taken from members of the general public in the UK undergoing a common and widely-used intervention. Whereas findings from studies of patients who have undergone bariatric surgery, for example, may not so easily generalise to the general population because bariatric surgery is not so widely available for weight loss, the findings of Chapters 3 and 4 (particularly Chapter 3 because of its scale) may be applied to other populations of participants undergoing open group behavioural weight management.

Whilst the use of a widely available open group behavioural weight loss intervention (Weight Watchers) was a strength of this thesis, it should be commented that this also limits the comparability of these findings to literature that has studied hedonic hunger in bariatric surgery studies. The discussion above highlighted the potential differing mechanism that may underlie changes in hedonic hunger in behavioural vs surgical weight loss. Weight loss following bariatric surgery occurs as a result of drastic physical changes being made to the gut that severely limit food intake. This may be influenced by altered gut hormone signalling between the gut and the brain that has been proposed to underlie neural changes in hedonic-reward brain responses to food which are observed after patients have undergone surgery (Goldstone et al., 2016). No measures of gut hormone changes during weight loss were taken for this thesis, and the underlying mechanism the

drives changes in hedonic hunger during behavioural weight loss has not been clearly defined, so current findings should be generalised to beyond a behavioural weight loss setting with care.

6.6.6. Measurement of attentional bias

This thesis utilised eye movement recordings (GD AB) to assess AB in addition to manual responses (RT AB) during the visual probe task in Chapters 4 and 5. This is in line with recommendations by Christiansen, Mansfield, Duckworth, Field and Jones (2015) that the reliability of the visual probe task in assessing AB is improved by with eye movement recordings, so had full data been available for assessment of GD AB in Chapter 4 and 5, the reliability of these measures would have been improved. An additional recommendation of Christiansen et al. (2015) is that the internal reliability of the visual probe task is improved by assessing AB using personalised, rather than generalised, stimuli. In their study, Christiansen et al. determined each participant's preference for alcoholic drinks and assessed AB to stimuli that represented this. Chapters 4 and 5 did not use personalised stimuli, so this could have impacted upon the sensitivity of the visual probe tasks employed in assessing AB. Chapter 5, however, deliberately recruited participants who self-identified as liking and regularly eating chocolate, and chocolate AB was assessed during the study. While not personalised to each participant and their preferred chocolate type/items, the chocolate stimuli may have been more salient to participants in Chapter 5 than the varied food stimuli used in in Chapter 4 was to participants. This is speculative, and repeating these studies using personalised stimuli may yield more reliable results.

Chapter 4 examined AB to food overall and specific to high calorie and low calorie foods by including food stimuli that represented both high and low calorie foods. This distinction between stimulus subsets allowed for more detailed analysis of AB than considering overall food stimuli would have done. Indeed, Chapter 4 showed that change in hedonic hunger was associated with change in AB to high calorie foods, particularly in participants with high baseline hedonic hunger. Including this distinction between high- and low calorie food stimuli is a strength of this thesis because it allowed this relationship to be detected, which would have otherwise been masked.

An additional consideration regarding the measurement of attentional bias relates to the use of the visual probe task. While the visual probe task is a widely used assessment of attentional bias (Field et al., 2016; Hendrikse et al., 2015; Werthmann et al., 2014), it is possible that an alternative AB assessment tool, such as the Stroop task, may have yielded different results. Calitri, Pothos, Tapper, Brunstrom and Rogers (2010) showed that attentional bias as measured by the interference effect on an emotional Stroop task predicted BMI change over a 1-year period. The Stroop task was not used in this thesis as there is debate surrounding how comparable the index of attentional bias calculated from the task compares to other assessment methods due to inconsistent AB findings in studies that used Stroop tasks (Hendrikse et al., 2015). Furthermore, behavioural measures of AB may in inferior to electrophysiological assessment measures. Nijs et al. (2010) showed that attention allocation to food cues as measured by neural response differed between participants with overweight/obesity and normal weight participants,

whereas responses on a visual probe task did not show the same distinction. Future

research should consider using different methods for measuring AB as a form of cue

reactivity to confirm if the findings presented here are particular to the visual probe

task, or AB itself.

6.7. Implications and future directions

Findings from this thesis support the hypothesis that high levels of hedonic

hunger present a barrier to weight loss success (Lowe et al., 2009; Lowe & Butryn,

2007). Chapter 3 showed that, compared to participants with low hedonic hunger,

when participants with high hedonic hunger were referred to Weight Watchers for

12 weeks (WW12), this intervention was less effective in reducing BMI at 12 months.

Referral to Weight Watchers for 12 weeks is a commonly used primary care

intervention in the UK (Weight Watchers, n.d.), so the implication of this finding is

that such interventions are less likely to achieve the same level of effectiveness in

individuals with high, as opposed to low, hedonic hunger. To express this in terms of

impact on the NHS, when participants with high hedonic hunger enter commonly

prescribed weight loss programmes (akin to WW12), they may lose less weight than

someone with low hedonic hunger. Maintaining excess weight may exacerbate or

increase their risk of developing health conditions that are related to obesity, such

as cardiovascular illness or diabetes. This, in turn, places greater strain on the NHS

as these individuals have additional healthcare needs and ultimately need additional

support because they may not be as successful at losing weight with traditional

methods. This theoretical proposal serves to reiterate the need for interventions that

aim to reduce elevated hedonic hunger to aid weight loss. Furthermore, these

findings suggest that people with higher hedonic hunger may need additional support at losing weight when using traditional methods, in order to be successful.

Chapter 3 demonstrated that hedonic hunger, and/or its underlying mechanism, is relatively stable over time. However, findings from Chapters 3 and 4 that hedonic hunger reduced during 12 weeks of weight loss, suggest that hedonic hunger is also potentially modifiable. The finding from Chapter 3 that early changes in hedonic hunger are predictive of BMI at 12 months suggests interventions that can reduce hedonic hunger may aid weight loss, particularly in individuals who demonstrate elevated high hedonic hunger when entering a weight management programme. Future research should try to identify interventions that can help to reduce hedonic hunger, and which can support people with high hedonic hunger, to lose weight.

In order to develop interventions that can reduce hedonic hunger, we need to understand more about the drivers and mechanisms of change in hedonic hunger. In this thesis, I focussed on attentional bias as a potential mechanism, as increased responsiveness to food cues is one of the proposed behavioural manifestations of hedonic hunger.

Chapter 4 showed that changes in hedonic hunger and changes in AB to high calorie foods were related, however Chapter 5 demonstrated that ABR is not an effective means of reducing hedonic hunger or AB. This implies that an additional factor was driving the reductions in AB and hedonic hunger detected in Chapter 4, and AB is not a candidate intervention target for reducing hedonic hunger. If future research is able to identify what drives the changes in hedonic hunger and BMI observed in Chapters 3 and 4, developing interventions that modify this may help to

reduce hedonic hunger and promote weight loss. Future research should consider exploring this in two ways. Firstly, future studies should consider employing a different means of assessing other aspects of food cue reactivity in individuals with high hedonic hunger, such as assessment of approach biases or desire to eat ratings. Evidence suggests that different assessments of food cue reactivity may be assessing differing manifestations of it (Nijs et al., 2010), which may mean that it is not through AB that food cue reactivity in higher hedonic hunger manifests.

The second recommendation for future research is in line with the proposal in Section 6.5 that hedonic hunger may be indicative of impulsive processes described in dual process models of obesity. If obesity results from an imbalance between impulsive and reflective processes (Hofmann et al., 2009), interventions that strengthen reflective processes may prove effective in managing the effects of impulsive processes, such as hedonic hunger. One such intervention may be inhibitory control training, which could strengthen reflective processes and help those with high hedonic hunger to resist eating in response to the experience of drives for palatable foods.

Additional recommendations that can be made from this thesis relate to the methodological issues that which have been highlighted in studies of food cue reactivity and hedonic hunger. Firstly, as Jones et al. (2017) comment, ABR studies are often underpowered to detect significant intervention effects. Future research needs to consider calculating more appropriate sample size recommendations when designing ABR interventions. Chapter 4 and 5 of this thesis were likely to have been statistically underpowered and may have benefitted from larger sample sizes.

Furthermore, Chapter 5 did not test the ABR intervention on individuals who explicitly reported a motivation to reduce chocolate consumption or lose weight, so the sample of participants did not represent the population for which the intervention would have been intended. This is a common issue in the ABR literature, as Jones et al. highlight, so it is unknown if such interventions would have different effects in more suitable populations. Future research should address this by being more selective in participant recruitment procedures to obtain a more representative study sample.

As discussed in Section 6.6.6, Christiansen et al. (2015) recommend that personalised stimuli are used in future AB studies. With regards to food cue reactivity, future research could implement this by identifying a participant's favourite foods, or type of food within a given category, and ensuring that these are used in AB assessments. Visual probe tasks that assess AB to chocolate are commonly used within the AB and ABR literature (e.g. Kemps et al., 2015), however participants may have individual preferences for types of chocolate within the stimulus category of "chocolate". For example, a participant reporting that they like chocolate may prefer dark chocolate, or dislike white chocolate or certain brands of chocolate confectionery. When a visual probe task presents this participant with images of white chocolate they may respond differently than they would to an image of dark chocolate, thus reducing the sensitivity of the task. Indeed, Christiansen et al. reported greater magnitudes of AB to personalised stimuli, than to generic stimuli, suggesting tasks with personalised stimuli were more sensitive to AB. Therefore, future research should use personalised stimuli when assessing food

cue reactivity to ensure individual differences in participant preferences do not minimise effects.

A final recommendation for future research that can be made from this thesis relates to the length of follow-up in longitudinal weight loss trials. Chapter 3 demonstrated that hedonic hunger at each measurement point predicted hedonic hunger at the subsequent time point, thus showing that either the construct of hedonic hunger, or its underlying mechanism, is relatively stable. Chapter 3 also demonstrated a predictive relationship between hedonic hunger and future BMI. These findings were detected during the 2-year WRAP trial, which represents the largest long-term assessment of hedonic hunger and BMI to date. However, the findings of this thesis cannot tell us more about the relationship between hedonic hunger and BMI beyond this time. As Bray, Kim and Wilding (2017) assert, obesity is a chronic, relapsing condition, and regain of lost weight is common following behavioural weight management (Wing, 2002), so in order to make longer-term predictions about the role of hedonic hunger in weight management and how weight may fluctuate in the years following an intervention, future research should repeat assessments over a longer time period. The National Heart, Lung and Blood Institute (1998) recommend that a 5-year follow up period for studies of weight management interventions is necessary to sufficiently evaluate their effectiveness. Future research that follows this recommendation should also assess hedonic hunger at follow-up assessments to explore how the predictive relationship between hedonic hunger and BMI observed in Chapter 3 may be related to weight

management over longer time periods. A 5-year follow up of the WRAP trial is currently planned, and data on hedonic hunger will be collected at this time point.

6.8. Conclusions

This thesis contributes to our understanding of hedonic hunger and food cue reactivity during weight management. The work carried out in this thesis establishes that hedonic hunger or its underlying mechanism is relatively stable over 2 years of weight management. This represents one of the largest studies to date of the relationship between hedonic hunger and BMI over time. I have also provided empirical evidence to support proposals that elevated hedonic hunger *is* a barrier to weight loss success, and individuals with elevated hedonic hunger may lose less weight and require additional weight loss support during short term behavioural weight loss interventions, such as those commonly prescribed in healthcare settings. Findings of this work also demonstrate that hedonic hunger reduces during weight loss, which indicates that hedonic hunger may be modifiable; therefore interventions that target this are likely to improve weight loss in individuals with elevated hedonic hunger. Furthermore, having examined food cue reactivity by assessing AB, this thesis demonstrates that while changes in hedonic hunger and AB are related in individuals who experience high hedonic hunger, AB may not be the means that the theoretical association between elevated hedonic hunger and food cue reactivity manifests. Finally, the work described here also demonstrates that ABR is unlikely to be an effective intervention for reducing hedonic hunger or food consumption in women with elevated hedonic hunger. When considered within the context of dual process theories of obesity, the findings of this thesis suggest that future work

should explore inhibitory control training as a means of reducing the additional

barrier to weight loss success that high hedonic hunger poses.

References

Adler, N. E., & Ostrove, J. M. (1999). Socioeconomic Status and Health: What We Know and What We Don't. *Annals of the New York Academy of Sciences*, *896*(1), 3–15. http://doi.org/10.1111/j.1749-6632.1999.tb08101.x

Adriaanse, M., de Ridder, D. T. D., & de Wit, J. B. F. (2009). Finding the critical cue: implementation intentions to change one's diet work best when tailored to personally relevant reasons for unhealthy eating. *Personality & Social Psychology Bulletin*, *35*(1), 60–71. http://doi.org/10.1177/0146167208325612

Ahern, A. L., Aveyard, P., Boyland, E. J., Halford, J. C., Jebb, S. A., & WRAP trial team. (2016). Inequalities in the uptake of weight management interventions in a pragmatic trial: an observational study in primary care. *The British Journal of General Practice: The Journal of the Royal College of General Practitioners*, *66*(645), e258-63. http://doi.org/10.3399/bjgp16X684337

Ahern, A. L., Aveyard, P. N., Halford, J. C., Mander, A., Cresswell, L., Cohn, S. R., … Jebb, S. A. (2014). Weight loss referrals for adults in primary care (WRAP): protocol for a multi-centre randomised controlled trial comparing the clinical and cost-effectiveness of primary care referral to a commercial weight loss provider for 12 weeks, referral for 52 week. *BMC Public Health*, *14*, 620. http://doi.org/10.1186/1471-2458-14-620

Ahern, A. L., Olson, A. D., Aston, L. M., & Jebb, S. A. (2011). Weight Watchers on prescription: An observational study of weight change among adults referred to

Weight Watchers by the NHS. *BMC Public Health*, *11*(1), 434. http://doi.org/10.1186/1471-2458-11-434

Ahern, A. L., Wheeler, G. M., Aveyard, P., Boyland, E. J., Halford, J. C. G., Mander, A. P., … Jebb, S. A. (2017). Extended and standard duration weight-loss programme referrals for adults in primary care (WRAP): a randomised controlled trial. *The Lancet*, *389*(10085), 2214–2225. http://doi.org/10.1016/S0140-6736(17)30647-5

Ahima, R. S., & Antwi, D. A. (2008). Brain regulation of appetite and satiety. *Endocrinology and Metabolism Clinics of North America*, *37*(4), 811–23. http://doi.org/10.1016/j.ecl.2008.08.005

Amir, N., Beard, C., Burns, M., & Bomyea, J. (2009). Attention modification program in individuals with generalized anxiety disorder. *Journal of Abnormal Psychology*, *118*(1), 28–33. http://doi.org/10.1037/a0012589

Angrisani, L., Santonicola, A., Iovino, P., Formisano, G., Buchwald, H., & Scopinaro, N. (2015). Bariatric surgery worldwide 2013. *Obesity Surgery*, *25*(10), 1822–1832. http://doi.org/10.1007/s11695-015-1657-z

Appelhans, B. M. (2009). Neurobehavioral inhibition of reward-driven feeding: implications for dieting and obesity. *Obesity (Silver Spring, Md.)*, *17*(4), 640–7. http://doi.org/10.1038/oby.2008.638

Appelhans, B. M., French, S. A., Pagoto, S. L., & Sherwood, N. E. (2016). Managing temptation in obesity treatment: A neurobehavioral model of intervention strategies. *Appetite*, *96*, 268–279. http://doi.org/10.1016/j.appet.2015.09.035

Appelhans, B. M., Woolf, K., Pagoto, S. L., Schneider, K. L., Whited, M. C., & Liebman, R. (2011). Inhibiting food reward: delay discounting, food reward sensitivity, and palatable food intake in overweight and obese women. *Obesity (Silver Spring, Md.)*, *19*(11), 2175–82. http://doi.org/10.1038/oby.2011.57

Armstrong, R. A. (2014). When to use the Bonferroni correction. *Ophthalmic and Physiological Optics*, *34*(5), 502–508. http://doi.org/10.1111/opo.12131

Attwood, A. S., O'Sullivan, H., Leonards, U., Mackintosh, B., & Munafò, M. R. (2008). Attentional bias training and cue reactivity in cigarette smokers. *Addiction (Abingdon, England)*, *103*(11), 1875–82. http://doi.org/10.1111/j.1360-0443.2008.02335.x

Baker, E. H. (2014). Socioeconomic Status, Definition. In *The Wiley Blackwell Encyclopedia of Health, Illness, Behavior, and Society* (pp. 2210–2214). Chichester, UK: John Wiley & Sons, Ltd. http://doi.org/10.1002/9781118410868.wbehibs395

Ball, K., & Crawford, D. (2005). Socioeconomic status and weight change in adults: a review. *Social Science & Medicine*, *60*(9), 1987–2010. http://doi.org/10.1016/j.socscimed.2004.08.056

Barbano, M. F., & Cador, M. (2005). Various aspects of feeding behavior can be partially dissociated in the rat by the incentive properties of food and the physiological state. *Behavioral Neuroscience*, *119*(5), 1244–1253. http://doi.org/10.1037/0735-7044.119.5.1244

Becker, D., Jostmann, N. B., Wiers, R. W., & Holland, R. W. (2015). Approach avoidance training in the eating domain: Testing the effectiveness across three single session studies. *Appetite*, *85*, 58–65. http://doi.org/10.1016/j.appet.2014.11.017

Beeken, L. (n.d.). New Weight Watchers Points System – ProPoints - Weight Loss Resources. Retrieved August 31, 2017, from http://www.weightlossresources.co.uk/diet/weight-watchers-propoints.htm

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588–606. http://doi.org/10.1037/0033-2909.88.3.588

Berridge, K. C. (2009). Liking and wanting food rewards: Brain substrates and roles in eating disorders. *Physiology & Behavior*, *97*(5), 537–550. http://doi.org/10.1016/j.physbeh.2009.02.044

Berridge, K. C., Ho, C.-Y., Richard, J. M., & DiFeliceantonio, A. G. (2010). The tempted brain eats: Pleasure and desire circuits in obesity and eating disorders. *Brain Research*, *1350*, 43–64. http://doi.org/10.1016/j.brainres.2010.04.003

Berridge, K. C., & Robinson, T. E. (2003). Parsing reward. *Trends in Neurosciences*, *26*(9), 507–513. http://doi.org/10.1016/S0166-2236(03)00233-9

Berthoud, H.-R. (2004). Neural control of appetite: cross-talk between homeostatic and non-homeostatic systems. *Appetite*, *43*(3), 315–317. http://doi.org/10.1016/j.appet.2004.04.009

Berthoud, H.-R. (2011). Metabolic and hedonic drives in the neural control of appetite: who is the boss? *Current Opinion in Neurobiology*, *21*(6), 888–896. http://doi.org/10.1016/j.conb.2011.09.004

Blechert, J., Meule, A., Busch, N. A., & Ohla, K. (2014). Food-pics: an image database for experimental research on eating and appetite. *Frontiers in Psychology*, *5*, 617. http://doi.org/10.3389/fpsyg.2014.00617

Blundell, J., Bryant, E., Lawton, C., Halford, J., Naslund, E., Finlayson, G., & King, N. (2010). *Characterizing the Homeostatic and Hedonic Markers of the Susceptible Phenotype*. *Obesity Prevention* (First edit). Elsevier Inc. http://doi.org/10.1016/B978-0-12-374387-9.00018-0

Blundell, J. E., & Finlayson, G. (2004). Is susceptibility to weight gain characterized by homeostatic or hedonic risk factors for overconsumption? *Physiology & Behavior*, *82*(1), 21–5. http://doi.org/10.1016/j.physbeh.2004.04.021

Blundell, J. E., Stubbs, R. J., Golding, C., Croden, F., Alam, R., Whybrow, S., ... Lawton, C. L. (2005). Resistance and susceptibility to weight gain: individual variability in response to a high-fat diet. *Physiology & Behavior*, *86*(5), 614–22. http://doi.org/10.1016/j.physbeh.2005.08.052

Bollen, K. A. (1989). A new incremental fit index for general structural equation models. *Sociological Methods & Research*, *17*(3), 303–316. http://doi.org/10.1177/0049124189017003004

Boswell, R. G., & Kober, H. (2016). Food cue reactivity and craving predict eating and

weight gain: a meta-analytic review. *Obesity Reviews*, *17*(2), 159–177. http://doi.org/10.1111/obr.12354

Bouhlal, S., McBride, C. M., Trivedi, N. S., Agurs-Collins, T., & Persky, S. (2017). Identifying eating behavior phenotypes and their correlates: A novel direction toward improving weight management interventions. *Appetite*, *111*, 142–150. http://doi.org/10.1016/j.appet.2016.12.006

Boutelle, K. N., Kuckertz, J. M., Carlson, J., & Amir, N. (2014). A pilot study evaluating a one-session attention modification training to decrease overeating in obese children. *Appetite*, *76*, 180–5. http://doi.org/10.1016/j.appet.2014.01.075

Boutelle, K. N., Monreal, T., Strong, D. R., & Amir, N. (2016). An open trial evaluating an attention bias modification program for overweight adults who binge eat. *Journal of Behavior Therapy and Experimental Psychiatry*, *52*, 138–46. http://doi.org/10.1016/j.jbtep.2016.04.005

Boyland, E. J., Harrold, J. A., Kirkham, T. C., & Halford, J. C. G. (2011). The extent of food advertising to children on UK television in 2008. *International Journal of Pediatric Obesity*, *6*(5–6), 455–461. http://doi.org/10.3109/17477166.2011.608801

Boyland, E. J., Randall-Smith, L., & Jones, A. (unpublished data). Attentional bias retraining and chocolate consumption.

Braet, C., & Crombez, G. (2003). Cognitive interference due to food cues in childhood obesity. *Journal of Clinical Child & Adolescent Psychology*, *32*(1), 32–

39. http://doi.org/10.1207/S15374424JCCP3201_04

Bray, G. A., & Bellanger, T. (2006). Epidemiology, Trends, and Morbidities of Obesity and the Metabolic Syndrome. *Endocrine*, *29*(1), 109–118. http://doi.org/10.1385/ENDO:29:1:109

Bray, G. A., Kim, K. K., & Wilding, J. P. H. (2017). Obesity: a chronic relapsing progressive disease process. A position statement of the World Obesity Federation. *Obesity Reviews*. http://doi.org/10.1111/obr.12551

British Heart Foundation. (2005). So you want to lose weight...for good - Booklet - BHF. Retrieved May 15, 2017, from https://www.bhf.org.uk/publications/large-print/so-you-want-to-lose-weight-for-good---large-print

Browne, M. W., & Cudeck, R. (1992). Alternative ways of assessing model fit. *Sociological Methods & Research*, *21*(2), 230–258. http://doi.org/10.1177/0049124192021002005

Buchwald, H., & Buchwald, J. N. (2002). Evolution of operative procedures for the management of morbid obesity 1950-2000. *Obesity Surgery*, *12*(5), 705–717. http://doi.org/10.1381/096089202321019747

Buchwald, H., & Williams, S. E. (2004). Bariatric surgery worldwide 2003. *Obesity Surgery*, *14*(9), 1157–1164. http://doi.org/10.1381/0960892042387057

Burger, K. S., Cornier, M. A., Ingebrigtsen, J., & Johnson, S. L. (2011). Assessing food appeal and desire to eat: the effects of portion size and energy density. *International Journal of Behavioral Nutrition and Physical Activity*, *8*(1), 101.

http://doi.org/10.1186/1479-5868-8-101

Burger, K. S., Sanders, A. J., & Gilbert, J. R. (2016). Hedonic hunger is related to increased neural and perceptual responses to cues of palatable food and motivation to consume: evidence from 3 independent investigations. *Journal of Nutrition*, *146*(9), 1807–1812. http://doi.org/10.3945/jn.116.231431

Burgoine, T., Forouhi, N. G., Griffin, S. J., Wareham, N. J., & Monsivais, P. (2014). Associations between exposure to takeaway food outlets, takeaway food consumption, and body weight in Cambridgeshire, UK: population based, cross sectional study. *BMJ*, *348*. Retrieved from http://www.bmj.com/content/348/bmj.g1464

Butland, B., Jebb, S., Kopelman, P., & Mcpherson, K. (2007). *Tackling obesities: future choices - project report (2nd edition)*. London. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287937/07-1184x-tackling-obesities-future-choices-report.pdf

Calitri, R., Pothos, E. M., Tapper, K., Brunstrom, J. M., & Rogers, P. J. (2010). Cognitive biases to healthy and unhealthy food words predict change in BMI. *Obesity*, *18*(12), 2282–2287. http://doi.org/10.1038/oby.2010.78

Cappelleri, J. C., Bushmakin, a G., Gerber, R. a, Leidy, N. K., Sexton, C. C., Karlsson, J., & Lowe, M. R. (2009). Evaluating the Power of Food Scale in obese subjects and a general sample of individuals: development and measurement properties. *International Journal of Obesity (2005)*, *33*(8), 913–22. http://doi.org/10.1038/ijo.2009.107

Carpenter, K. M., Hasin, D. S., Allison, D. B., & Faith, M. S. (2000). Relationships between obesity and DSM-IV major depressive disorder, suicide ideation, and suicide attempts: results from a general population study. *American Journal of Public Health*, *90*(2), 251–7. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10667187

Carter, B. L., & Tiffany, S. T. (1999). Meta-analysis of cue-reactivity in addiction research. *Addiction*, *94*(3), 327–340. http://doi.org/10.1046/j.1360-0443.1999.9433273.x

Castellanos, E. H., Charboneau, E., Dietrich, M. S., Park, S., Bradley, B. P., Mogg, K., & Cowan, R. L. (2009). Obese adults have visual attention bias for food cue images: evidence for altered reward system function. *International Journal of Obesity*, *33*(9), 1063–1073. http://doi.org/10.1038/ijo.2009.138

Celio, A. C., & Pories, W. J. (2016). A history of bariatric surgery. *Surgical Clinics of North America*, *96*(4), 655–667. http://doi.org/10.1016/j.suc.2016.03.001

Chen, Z., Veling, H., Dijksterhuis, A., & Holland, R. W. (2016). How does not responding to appetitive stimuli cause devaluation: Evaluative conditioning or response inhibition? *Journal of Experimental Psychology: General*, *145*(12), 1687–1701. http://doi.org/10.1037/xge0000236

Cheung, B. M. Y., Cheung, T. T., & Samaranayake, N. R. (2013). Safety of antiobesity drugs. *Therapeutic Advances in Drug Safety*, *4*(4), 171–81. http://doi.org/10.1177/2042098613489721

Choquet, H., & Meyre, D. (2011). Genetics of obesity: What have we learned? *Current Genomics*, *12*(3), 169–79. http://doi.org/10.2174/138920211795677895

Christiansen, P., Mansfield, R., Duckworth, J., Field, M., & Jones, A. (2015). Internal reliability of the alcohol-related visual probe task is increased by utilising personalised stimuli and eye-tracking. *Drug and Alcohol Dependence*, *155*, 170–174. http://doi.org/10.1016/j.drugalcdep.2015.07.672

Cummings, D. E. (2006). Ghrelin and the short- and long-term regulation of appetite and body weight. *Physiology & Behavior*, *89*(1), 71–84. http://doi.org/10.1016/j.physbeh.2006.05.022

Cushing, C. C., Benoit, S. C., Peugh, J. L., Reiter-Purtill, J., Inge, T. H., & Zeller, M. H. (2014). Longitudinal trends in hedonic hunger after Roux-en-Y gastric bypass in adolescents. *Surgery for Obesity and Related Diseases : Official Journal of the American Society for Bariatric Surgery*, *10*(1), 125–30. http://doi.org/10.1016/j.soard.2013.05.009

Davis, C. a, Levitan, R. D., Reid, C., Carter, J. C., Kaplan, A. S., Patte, K., ... Kennedy, J. L. (2009). Dopamine for "wanting" and opioids for "liking": a comparison of obese adults with and without binge eating. *Obesity*, *17*(6), 1220–1225. http://doi.org/10.1038/oby.2009.52

Di Marzo, V., Ligresti, A., & Cristino, L. (2009). The endocannabinoid system as a link between homoeostatic and hedonic pathways involved in energy balance regulation. *International Journal of Obesity*, *33*, S18–S24. http://doi.org/10.1038/ijo.2009.67

Dickson, H., Kavanagh, D. J., & MacLeod, C. (2016). The pulling power of chocolate: Effects of approach–avoidance training on approach bias and consumption. *Appetite*, *99*, 46–51. http://doi.org/10.1016/j.appet.2015.12.026

Doolan, K. J., Breslin, G., Hanna, D., & Gallagher, M. (2014). Attentional bias to food-related visual cues: is there a role in obesity? *Proceedings of the Nutrition Society*, *74,* 37–45. http://doi.org/10.1017/S002966511400144X

Doolan, K. J., Breslin, G., Hanna, D., Murphy, K., & Gallagher, A. M. (2014). Visual attention to food cues in obesity: an eye-tracking study. *Obesity*, *22*(12), 2501–7. http://doi.org/10.1002/oby.20884

Drummond, D. C. (2000). What does cue-reactivity have to offer clinical research? *Addiction*, *95*(8s2), 129–144. http://doi.org/10.1046/j.1360-0443.95.8s2.2.x

Ely, A. V, Howard, J., & Lowe, M. R. (2015). Delayed discounting and hedonic hunger in the prediction of lab-based eating behavior. *Eating Behaviors*, *19*, 72–5. http://doi.org/10.1016/j.eatbeh.2015.06.015

Epstein, L. H., & Leddy, J. J. (2006). Food reinforcement. *Appetite*, *46*(1), 22–25. http://doi.org/10.1016/j.appet.2005.04.006

European Snacks Association. (2014). The European Savoury Snack Market. Retrieved June 23, 2015, from http://www.esasnacks.eu/europe-statistics.php

Fairburn, C. G., & Cooper, P. J. (1984). The clinical features of bulimia nervosa. *The British Journal of Psychiatry*, *144*(3). https:// 10.1192/bjp.144.3.238

Falkner, N. H., French, S. A., Jeffery, R. W., Neumark-Sztainer, D., Sherwood, N. E., &

Morton, N. (1999). Mistreatment due to weight: prevalence and sources of perceived mistreatment in women and men. *Obesity Research*, *7*(6), 572–6. https:// 10.1002/j.1550-8528.1999.tb00716.x

Farooqi, I. S. (2005). Genetic and hereditary aspects of childhood obesity. *Best Practice & Research Clinical Endocrinology & Metabolism*, *19*(3), 359–374. http://doi.org/10.1016/j.beem.2005.04.004

Ferriday, D., & Brunstrom, J. M. (2011). "I just can"t help myself': effects of food-cue exposure in overweight and lean individuals. *International Journal of Obesity*, *35*(1), 142–149. http://doi.org/10.1038/ijo.2010.117

Field, M., & Cox, W. (2008). Attentional bias in addictive behaviors: A review of its development, causes, and consequences. *Drug and Alcohol Dependence*, *97*(1–2), 1–20. http://doi.org/10.1016/j.drugalcdep.2008.03.030

Field, M., Duka, T., Tyler, E., & Schoenmakers, T. (2009). Attentional bias modification in tobacco smokers. *Nicotine & Tobacco Research: Official Journal of the Society for Research on Nicotine and Tobacco*, *11*(7), 812–22. http://doi.org/10.1093/ntr/ntp067

Field, M., & Eastwood, B. (2005). Experimental manipulation of attentional bias increases the motivation to drink alcohol. *Psychopharmacology*, *183*(3), 350–7. http://doi.org/10.1007/s00213-005-0202-5

Field, M., Eastwood, B., Bradley, B. P., & Mogg, K. (2006). Selective processing of cannabis cues in regular cannabis users. *Drug and Alcohol Dependence*, *85*(1),

75–82. http://doi.org/10.1016/j.drugalcdep.2006.03.018

Field, M., Werthmann, J., Franken, I., Hofmann, W., Hogarth, L., & Roefs, A. (2016). The role of attentional bias in obesity and addiction. *Health Psychology*, *35*(8), 767–780. http://doi.org/10.1037/hea0000405

Finlayson, G., Cecil, J., Higgs, S., Hill, A., & Hetherington, M. (2012). Susceptibility to weight gain. Eating behaviour traits and physical activity as predictors of weight gain during the first year of university. *Appetite*, *58*(3), 1091–8. http://doi.org/10.1016/j.appet.2012.03.003

Finley, C. E., Barlow, C. E., Greenway, F. L., Rock, C. L., Rolls, B. J., & Blair, S. N. (2007). Retention rates and weight loss in a commercial weight loss program. *International Journal of Obesity*, *31*(2), 292–298. http://doi.org/10.1038/sj.ijo.0803395

Fisher, J. O., & Birch, L. L. (1999). Restricting access to foods and children's eating. *Appetite*, *32*(3), 405–419. http://doi.org/10.1006/appe.1999.0231

Fobi, M. A. L., Lee, H., Holness, R., & Cabinda, D. (1998). Gastric Bypass Operation for Obesity. *World Journal of Surgery*, *22*(9), 925–935. http://doi.org/10.1007/s002689900496

Food and Agriculture Organization of the United Nations. (2013). *The State of Food and Agriculture*. Retrieved from http://www.fao.org/docrep/018/i3300e/i3300e.pdf

Freedman, D. S., Khan, L. K., Serdula, M. K., Dietz, W. H., Srinivasan, S. R., & Berenson,

G. S. (2005). The relation of childhood BMI to ddult adiposity: The Bogalusa Heart Study. *Pediatrics*, *115*(1). Retrieved from http://pediatrics.aappublications.org/content/115/1/22

French, D. P., & Sutton, S. (2010). Reactivity of measurement in health psychology: How much of a problem is it? What can be done about it? *British Journal of Health Psychology*, *15*(3), 453–468. http://doi.org/10.1348/135910710X492341

Goldstone, A. P., Miras, A. D., Scholtz, S., Jackson, S., Neff, K. J., Pénicaud, L., … le Roux, C. W. (2016). Link between increased satiety gut hormones and reduced food reward after gastric bypass surgery for obesity. *The Journal of Clinical Endocrinology & Metabolism*, *101*(2), 599–609. http://doi.org/10.1210/jc.2015-2665

Goldstone, A. P., Prechtl de Hernandez, C. G., Beaver, J. D., Muhammed, K., Croese, C., Bell, G., … Bell, J. D. (2009). Fasting biases brain reward systems towards high-calorie foods. *European Journal of Neuroscience*, *30*(8), 1625–1635. http://doi.org/10.1111/j.1460-9568.2009.06949.x

Greenberg, J. A., Buijsse, B., Perkins, G., Fitzgerald, P., & Adams, V. (2013). Habitual Chocolate Consumption May Increase Body Weight in a Dose-Response Manner. *PLoS ONE*, *8*(8), e70271. http://doi.org/10.1371/journal.pone.0070271

Griffiths, L. J., Dezateux, C., & Hill, A. (2011). Is obesity associated with emotional and behavioural problems in children? Findings from the Millennium Cohort Study. *International Journal of Pediatric Obesity*, *6*(2–2), e423–e432. http://doi.org/10.3109/17477166.2010.526221

Griffiths, L. J., Parsons, T. J., & Hill, A. J. (2010). Self-esteem and quality of life in obese children and adolescents: A systematic review. *International Journal of Pediatric Obesity*, *5*(4), 282–304. http://doi.org/10.3109/17477160903473697

Gudzune, K. A., Doshi, R. S., Mehta, A. K., Chaudhry, Z. W., Jacobs, D. K., Vakil, R. M., … Clark, J. M. (2015). Efficacy of commercial weight-loss programs: an updated systematic review. *Annals of Internal Medicine*, *162*(7), 501–12. http://doi.org/10.7326/M14-2238

Haedt-Matt, A. A., & Keel, P. K. (2011). Hunger and binge eating: a meta-analysis of studies using ecological momentary assessment. *The International Journal of Eating Disorders*, *44*(7), 573–8. http://doi.org/10.1002/eat.20868

Hainer, V., Toplak, H., & Mitrakou, A. (2008). Treatment Modalities of Obesity: What fits whom? *Diabetes Care*, *31*(Supplement 2), S269–S277. http://doi.org/10.2337/dc08-s265

Halford, J. C. G., Boyland, E. J., Blundell, J. E., Kirkham, T. C., & Harrold, J. A. (2010). Pharmacological management of appetite expression in obesity. *Nature Reviews. Endocrinology*, *6*(5), 255–69. http://doi.org/10.1038/nrendo.2010.19

Hansen, T. T., Jakobsen, T. A., Nielsen, M. S., Sjödin, A., Le Roux, C. W., & Schmidt, J. B. (2016). Hedonic Changes in Food Choices Following Roux-en-Y Gastric Bypass. *Obesity Surgery*, *26*(8), 1946–1955. http://doi.org/10.1007/s11695-016-2217-x

Hardman, C. A., Jones, A., Field, M., & Werthmann, J. (2017). The associations

between food-related visual attentional bias, body weight and appetitive motivation: A systematic review and meta-analysis. In *Proceedings of the British Feeding and Drinking Group Annual Meeting*. Reading, UK.

Hardman, C. A, Rogers, P. J., Etchells, K. A, Houstoun, K. V. E., & Munafò, M. R. (2013). The effects of food-related attentional bias training on appetite and food intake. *Appetite*, *71*, 295–300. http://doi.org/10.1016/j.appet.2013.08.021

Harrison, S., Rowlinson, M., & Hill, A. J. (2016). "No fat friend of mine": Young children's responses to overweight and disability. *Body Image*, *18*, 65–73. http://doi.org/10.1016/j.bodyim.2016.05.002

Harrold, J. A., Dovey, T. M., Blundell, J. E., & Halford, J. C. G. (2012). CNS regulation of appetite. *Neuropharmacology*, *63*(1), 3–17. http://doi.org/10.1016/j.neuropharm.2012.01.007

Hartmann-Boyce, J., Johns, D. J., Jebb, S. A., Summerbell, C., Aveyard, P., & Behavioural Weight Management Review Group. (2014). Behavioural weight management programmes for adults assessed by trials conducted in everyday contexts: systematic review and meta-analysis. *Obesity Reviews*, *15*(11), 920–932. http://doi.org/10.1111/obr.12220

Harvey, S. B., Glozier, N., Carlton, O., Mykletun, A., Henderson, M., Hotopf, M., & Holland-Elliott, K. (2010). Obesity and sickness absence: results from the CHAP study. *Occupational Medicine*, *60*(5), 362–368. http://doi.org/10.1093/occmed/kqq031

Hashim, S. A., & Van Italllie, T. B. (1965). Cholestyramine Resin Therapy for Hypercholesteremia. *JAMA*, *192*(4), 289. http://doi.org/10.1001/jama.1965.03080170017004

Havermans, R. C., Giesen, J. C. A. H., Houben, K., & Jansen, A. (2011). Weight, gender, and snack appeal. *Eating Behaviours*, *12*(2), 126-130. http://doi.org/10.1016/j.eatbeh.2011.01.010

Hendrikse, J. J., Cachia, R. L., Kothe, E. J., McPhie, S., Skouteris, H., & Hayden, M. J. (2015). Attentional biases for food cues in overweight and individuals with obesity: a systematic review of the literature. *Obesity Reviews*, *16*(5), 424–432. http://doi.org/10.1111/obr.12265

Hetherington, M. M. (1996). Sensory-specific satiety and its importance in meal termination. *Neuroscience and Biobehavioral Reviews*, *20*(1), 113–7. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8622817

Hetherington, M., Rolls, B. J., & Burley, V. J. (1989). The time course of sensory-specific satiety. *Appetite*, *12*(1), 57–68. http://doi.org/10.1016/0195-6663(89)90068-8

Higgs, S., Williamson, A. C., & Attwood, A. S. (2008). Recall of recent lunch and its effect on subsequent snack intake. *Physiology & Behavior*, *94*(3), 454–462. http://doi.org/10.1016/j.physbeh.2008.02.011

Hill, C., Llewellyn, C. H., Saxton, J., Webber, L., Semmler, C., Carnell, S., ... Wardle, J. (2008). Adiposity and "eating in the absence of hunger" in children.

International Journal of Obesity, *32*(10), 1499–1505. http://doi.org/10.1038/ijo.2008.113

Hofmann, W., Friese, M., & Strack, F. (2009). Impulse and self-control from a dual-systems perspective. *Perspectives on Psychological Science*, *4*(2), 162–176. http://doi.org/10.1111/j.1745-6924.2009.01116.x

Holsen, L. M., Lawson, E. A., Blum, J., Ko, E., Makris, N., Fazeli, P. K., ... Goldstein, J. M. (2012). Food motivation circuitry hypoactivation related to hedonic and nonhedonic aspects of hunger and satiety in women with active anorexia nervosa and weight-restored women with anorexia nervosa. *Journal of Psychiatry & Neuroscience : JPN*, *37*(5), 322–32. http://doi.org/10.1503/jpn.110156

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. http://doi.org/10.1080/10705519909540118

Husted, M., & Ogden, J. (2014). Emphasising personal investment effects weight loss and hedonic thoughts about food after obesity surgery. *Journal of Obesity*, *2014*, 810374. http://doi.org/10.1155/2014/810374

Hwang, K. O., Ning, J., Trickey, A. W., & Sciamanna, C. N. (2013). Website usage and weight loss in a free commercial online weight loss program: retrospective cohort study. *Journal of Medical Internet Research*, *15*(1), e11. http://doi.org/10.2196/jmir.2195

Irish Food Board. (2014). *Snacking In Ireland and UK – Full Report*. Retrieved from http://www.bordbia.ie/industry/manufacturers/insight/publications/bbreports/ Documents/Full Report - Snacking Report Ireland and UK.pdf

James, W. P. T. (2008). WHO recognition of the global obesity epidemic. *International Journal of Obesity*, *32*, S120–S126. http://doi.org/10.1038/ijo.2008.247

Jansen, A. (1998). A learning model of binge eating: Cue reactivity and cue exposure. *Behaviour Research and Therapy*, *36*(3), 257–272. http://doi.org/10.1016/S0005-7967(98)00055-2

Jansen, A., Houben, K., & Roefs, A. (2015). A cognitive profile of obesity and its translation into new interventions. *Frontiers in Psychology*, *6*, 1807. http://doi.org/10.3389/fpsyg.2015.01807

Jansen, A., Vanreyten, A., van Balveren, T., Roefs, A., Nederkoorn, C., & Havermans, R. (2008). Negative affect and cue-induced overeating in non-eating disordered obesity. *Appetite*, *51*(3), 556–562. http://doi.org/10.1016/j.appet.2008.04.009

Jebb, S. A., Ahern, A. L., Olson, A. D., Aston, L. M., Holzapfel, C., Stoll, J., ... Caterson, I. D. (2011). Primary care referral to a commercial provider for weight loss treatment versus standard care: a randomised controlled trial. *Lancet*, *378*(9801), 1485–92. http://doi.org/10.1016/S0140-6736(11)61344-5

Jensen, C. D., Duraccio, K. M., Carbine, K. A., Barnett, K. A., & Kirwan, C. B. (2016). Motivational impact of palatable food correlates with functional brain

responses to food images in adolescents. *Journal of Pediatric Psychology, 42(5),* 578-587. http://doi.org/10.1093/jpepsy/jsw091

Jerlhag, E., Egecioglu, E., Dickson, S. L., Douhan, A., Svensson, L., & Engel, J. A. (2007). Ghrelin administration into tegmental areas stimulates locomotor activity and increases extracellular concentration of dopamine in the nucleus accumbens. *Addiction Biology*, *12*(1), 6–16. http://doi.org/10.1111/j.1369-1600.2006.00041.x

Johnson, F., & Wardle, J. (2011). The association between weight loss and engagement with a web-based food and exercise diary in a commercial weight loss programme: a retrospective analysis. *The International Journal of Behavioral Nutrition and Physical Activity*, *8*, 83. http://doi.org/10.1186/1479-5868-8-83

Johnston, D. W., & Lordan, G. (2014). Weight perceptions, weight control and income: An analysis using British data. *Economics & Human Biology*, *12*, 132–139. http://doi.org/10.1016/j.ehb.2013.02.004

Jolly, K., Lewis, A., Beach, J., Denley, J., Adab, P., Deeks, J. J., … Aveyard, P. (2011). Comparison of range of commercial or primary care led weight reduction programmes with minimal intervention control for weight loss in obesity: lighten Up randomised controlled trial. *BMJ (Clinical Research Ed.)*, *343*(nov03_2), d6500. http://doi.org/10.1136/bmj.d6500

Jones, A., Bentham, G., Foster, C., Hillsdon, M., & Panter, J. (2007). *Tackling Obesities: Future Choices – Obesogenic Environments – Evidence Review*. Retrieved from https://www.researchgate.net/profile/Andy_Jones3/publication/252029378_Tac

kling_Obesities_Future_Choices_-_Obesogenic_Environments_-_Evidence_Review/links/00463539592c87995b000000.pdf

Jones, A., Button, E., Rose, A. K., Robinson, E., Christiansen, P., Di Lemma, L., & Field, M. (2016). The ad-libitum alcohol "taste test": secondary analyses of potential confounds and construct validity. *Psychopharmacology*, *233*(5), 917–924. http://doi.org/10.1007/s00213-015-4171-z

Jones, A., Hardman, C. A., Lawrence, N., & Field, M. (2017). Cognitive training as a potential treatment for overweight and obesity: A critical review of the evidence. *Appetite*. http://doi.org/10.1016/j.appet.2017.05.032

Kakoschke, N., Kemps, E., & Tiggemann, M. (2014). Attentional bias modification encourages healthy eating. *Eating Behaviors*, *15*(1), 120–124. http://doi.org/10.1016/j.eatbeh.2013.11.001

Kaplan, L. (2003). Body Weight Regulation and Obesity. *Journal of Gastrointestinal Surgery*, *7*(4), 443–451. http://doi.org/10.1016/S1091-255X(03)00047-7

Kasen, S., Cohen, P., Chen, H., & Must, A. (2008). Obesity and psychopathology in women: a three decade prospective study. *International Journal of Obesity*, *32*(3), 558–566. http://doi.org/10.1038/sj.ijo.0803736

Kemps, E., Tiggemann, M., & Elford, J. (2015). Sustained effects of attentional re-training on chocolate consumption. *Journal of Behavior Therapy and Experimental Psychiatry*, *49*(Pt A), 94–100. http://doi.org/10.1016/j.jbtep.2014.12.001

Kemps, E., Tiggemann, M., & Hollitt, S. (2014). Biased attentional processing of food cues and modification in obese individuals. *Health Psychology*, *American Psychological Association*, *33*(11), 1391–401. http://doi.org/10.1037/hea0000069

Kemps, E., Tiggemann, M., Martin, R., & Elliott, M. (2013). Implicit approach-avoidance associations for craved food cues. *Journal of Experimental Psychology. Applied*, *19*(1), 30–8. http://doi.org/10.1037/a0031626

Kemps, E., Tiggemann, M., Orr, J., & Grear, J. (2014). Attentional retraining can reduce chocolate consumption. *Journal of Experimental Psychology. Applied*, *20*(1), 94–102. http://doi.org/10.1037/xap0000005

Kim, U. K., Jorgenson, E., Coon, H., Leppert, M., Risch, N., & Drayna, D. (2003). Positional cloning of the human quantitative trait locus underlying taste sensitivity to phenylthiocarbamide. *Science*, *299*(5610), 1221–1225. http://doi.org/10.1126/science.1080190

Kojima, M., Hosoda, H., Date, Y., Nakazato, M., Matsuo, H., & Kangawa, K. (1999). Ghrelin is a growth-hormone-releasing acylated peptide from stomach. *Nature*, *402*(6762), 656–660. http://doi.org/10.1038/45230

Kojima, M., Hosoda, H., & Kangawa, K. (2004). Ghrelin, a novel growth-hormone-releasing and appetite-stimulating peptide from stomach. *Best Practice & Research Clinical Endocrinology & Metabolism*, *18*(4), 517–530. http://doi.org/10.1016/j.beem.2004.07.001

Kremers, S., Reubsaet, A., Martens, M., Gerards, S., Jonkers, R., Candel, M., … De Vries,

N. (2010). Systematic prevention of overweight and obesity in adults: a qualitative and quantitative literature analysis. *Obesity Reviews*, *11*(5), 371–379. http://doi.org/10.1111/j.1467-789X.2009.00598.x

Kremers, S., Reubsaet, A., Martens, M., Gerards, S., Jonkers, R., Candel, M., … de Vries, N. (2010). Systematic prevention of overweight and obesity in adults: a qualitative and quantitative literature analysis. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, *11*(5), 371–9. http://doi.org/10.1111/j.1467-789X.2009.00598.x

Kushi, L. H., Byers, T., Doyle, C., Bandera, E. V., McCullough, M., Gansler, T., … Thun, M. J. (2006). American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Prevention: Reducing the Risk of Cancer With Healthy Food Choices and Physical Activity. *CA: A Cancer Journal for Clinicians*, *56*(5), 254–281. http://doi.org/10.3322/canjclin.56.5.254

Kyle, T. K., Dhurandhar, E. J., & Allison, D. B. (2016). Regarding obesity as a disease. *Endocrinology and Metabolism Clinics of North America*, *45*(3), 511–520. http://doi.org/10.1016/j.ecl.2016.04.004

Lake, A., & Townshend, T. (2006). Obesogenic environments: exploring the built and food environments. *The Journal of the Royal Society for the Promotion of Health*, *126*(6), 262–267. http://doi.org/10.1177/1466424006070487

Lasikiewicz, N., Myrissa, K., Hoyland, A., & Lawton, C. L. (2014). Psychological benefits of weight loss following behavioural and/or dietary weight loss interventions. A systematic research review. *Appetite*, *72*, 123–137.

http://doi.org/10.1016/j.appet.2013.09.017

Lattimore, P., & Mead, B. R. (2015). See it, grab it, or STOP! Relationships between trait impulsivity, attentional bias for pictorial food cues and associated response inhibition following in-vivo food cue exposure. *Appetite*, *90*¸248-253. http://doi.org/10.1016/j.appet.2015.02.020

Laurent, J. S. (2015). Psychometric properties for the Children's Power of Food Scale in a diverse sample of pre-adolescent youth. *Applied Nursing Research*, *28*, 127–131. http://doi.org/10.1016/j.apnr.2014.09.001

Lavin, J. H., Avery, A., Whitehead, S. M., Rees, E., Parsons, J., Bagnall, T., ... Ruxton, C. H. S. (2006). Feasibility and benefits of implementing a Slimming on Referral service in primary care using a commercial weight management partner. *Public Health*, *120*(9), 872–81. http://doi.org/10.1016/j.puhe.2006.05.008

Lawrence, N. S., Hinton, E. C., Parkinson, J. A., & Lawrence, A. D. (2012). Nucleus accumbens response to food cues predicts subsequent snack consumption in women and increased body mass index in those with reduced self-control. *NeuroImage*, *63*(1), 415–422. http://doi.org/10.1016/j.neuroimage.2012.06.070

Li, M., & Cheung, B. M. Y. (2009). Pharmacotherapy for obesity. *British Journal of Clinical Pharmacology*, *68*(6), 804–10. http://doi.org/10.1111/j.1365-2125.2009.03453.x

Lipsky, L. M., Nansel, T. R., Haynie, D. L., Liu, D., Eisenberg, M. H., & Simons-Morton, B. (2016). Power of Food Scale in association with weight outcomes and dieting

in a nationally representative cohort of U.S. young adults. *Appetite*, *105*, 385–391. http://doi.org/10.1016/j.appet.2016.06.012

Lowe, M. R., Arigo, D., Butryn, M. L., Gilbert, J. R., Sarwer, D., & Stice, E. (2016). Hedonic hunger prospectively predicts onset and maintenance of loss of control eating among college women. *Health Psychology, 35*(3), 238–244. http://dx.doi.org/10.1037/hea0000291

Lowe, M. R., & Butryn, M. L. (2007). Hedonic hunger: a new dimension of appetite? *Physiology & Behavior*, *91*(4), 432–9. http://doi.org/10.1016/j.physbeh.2007.04.006

Lowe, M. R., Butryn, M. L., Didie, E. R., Annunziato, R. A., Thomas, J. G., Crerand, C. E., … Halford, J. (2009). The Power of Food Scale. A new measure of the psychological influence of the food environment. *Appetite*, *53*(1), 114–118. http://doi.org/10.1016/j.appet.2009.05.016

Lowe, M. R., Kral, T. V. E., & Miller-Kovach, K. (2008). Weight-loss maintenance 1, 2 and 5 years after successful completion of a weight-loss programme. *The British Journal of Nutrition*, *99*(4), 925–30. http://doi.org/10.1017/S0007114507862416

Lowe, M. R., & Levine, A. S. (2005). Eating motives and the controversy over dieting: eating less than needed versus less than wanted. *Obesity Research*, *13*(5), 797–806. http://doi.org/10.1038/oby.2005.90

Luppino, F. S., de Wit, L. M., Bouvy, P. F., Stijnen, T., Cuijpers, P., Penninx, B. W. J. H., …

CN, B. M. (2010). Overweight, Obesity, and Depression. *Archives of General Psychiatry*, *67*(3), 220. http://doi.org/10.1001/archgenpsychiatry.2010.2

Lutter, M., & Nestler, E. J. (2009). Homeostatic and hedonic signals interact in the regulation of food intake. *The Journal of Nutrition*, *139*(3), 629–32. http://doi.org/10.3945/jn.108.097618

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, *95*(1), 15–20. http://doi.org/10.1037/0021-843X.95.1.15

MacNeill, V., Foley, M., Quirk, A., & McCambridge, J. (2016). Shedding light on research participation effects in behaviour change trials: a qualitative study examining research participant experiences. *BMC Public Health*, *16*(1), 91. http://doi.org/10.1186/s12889-016-2741-6

Madigan, C. D., Daley, A. J., Lewis, A. L., Jolly, K., & Aveyard, P. (2014). Which weight-loss programmes are as effective as Weight Watchers®?: non-inferiority analysis. *The British Journal of General Practice*, *64*(620), e128-36. http://doi.org/10.3399/bjgp14X677491

Maguire, E. R., Burgoine, T., & Monsivais, P. (2015). Area deprivation and the food environment over time: A repeated cross-sectional study on takeaway outlet density and supermarket presence in Norfolk, UK, 1990–2008. *Health & Place*, *33*, 142–147. http://doi.org/10.1016/j.healthplace.2015.02.012

Manasse, S. M., Espel, H. M., Forman, E. M., Ruocco, A. C., Juarascio, A. S., Butryn, M.

L., ... Lowe, M. R. (2015). The independent and interacting effects of hedonic hunger and executive function on binge eating. *Appetite*, *89*, 16–21. http://doi.org/10.1016/j.appet.2015.01.013

Monteleone, M. A., Monteleone, P., Dalle Grave, R., Nigro, M., El Ghoch, M., Calugi, S., ... Maj, M. (2016). Ghrelin response to hedonic eating in underweight and short-term weight restored patients with anorexia nervosa. *Psychiatry Research*, *235*, 55–60. http://doi.org/10.1016/j.psychres.2015.12.001

Marks, K. R., Pike, E., Stoops, W. W., & Rush, C. R. (2014). Test–retest reliability of eye tracking during the visual probe task in cocaine-using adults. *Drug and Alcohol Dependence*, *145*, 235–237. http://doi.org/10.1016/j.drugalcdep.2014.09.784

Mattes, R. (1990). Hunger ratings are not a valid proxy measure of reported food intake in humans. *Appetite*, *15*(2), 103–113. http://doi.org/10.1016/0195-6663(90)90043-8

McCoy, S., Campbell, K., Lassemillante, A. C., Wallen, M., Fawcett, J., Jarrett, M., ... Hickman, I. (2017). Changes in dietary patterns and body composition within 12 months of liver transplantation. *Hepatobiliary Surgery and Nutrition*. http://doi.org/http://dx.doi.org/10.21037/hbsn.2017.01.12

McLaren, L. (2007). Socioeconomic Status and Obesity. *Epidemiologic Reviews*, *29*(1), 29–48. http://doi.org/10.1093/epirev/mxm001

Mintel International Group Ltd. (2016). Chocolate Confectionery - UK - April 2016 - Market Research Report. Retrieved May 1, 2017, from

http://academic.mintel.com.liverpool.idm.oclc.org/display/748194/

Miras, A. D., Jackson, R. N., Jackson, S. N., Goldstone, A. P., Olbers, T., Hackenberg, T.,
… le Roux, C. W. (2012). Gastric bypass surgery for obesity decreases the reward
value of a sweet-fat stimulus as assessed in a progressive ratio task. *The
American Journal of Clinical Nutrition*, *96*(3), 467–73.
http://doi.org/10.3945/ajcn.112.036921

Mitchell, T. B., Cushing, C. C., & Amaro, C. M. (2016). Psychometric properties of the
Power of Food Scale in a community sample of preadolescents and
adolescents. *Journal of Child and Family Studies*, *25*(9), 2733–2739.
http://doi.org/10.1007/s10826-016-0444-3

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual
differences in executive functions: four general conclusions. *Current Directions
in Psychological Science*, *21*(1), 8–14. http://doi.org/10.1177/0963721411429458

Monteleone, A. M., Di Marzo, V., Aveta, T., Piscitelli, F., Dalle Grave, R., Scognamiglio,
P., … Maj, M. (2015). Deranged endocannabinoid responses to hedonic eating
in underweight and recently weight-restored patients with anorexia nervosa.
The American Journal of Clinical Nutrition, *101*(2), 262–9.
http://doi.org/10.3945/ajcn.114.096164

Monteleone, A. M., Di Marzo, V., Monteleone, P., Dalle Grave, R., Aveta, T., Ghoch, M.
El, … Maj, M. (2016). Responses of peripheral endocannabinoids and
endocannabinoid-related compounds to hedonic eating in obesity. *European
Journal of Nutrition*, *55*(4), 1799–1805. http://doi.org/10.1007/s00394-016-

1153-9

Monteleone, P., Piscitelli, F., Scognamiglio, P., Monteleone, A. M., Canestrelli, B., Di Marzo, V., & Maj, M. (2012). Hedonic eating is associated with increased peripheral levels of ghrelin and the endocannabinoid 2-arachidonoyl-glycerol in healthy humans: a pilot study. *The Journal of Clinical Endocrinology and Metabolism*, *97*(6), E917-24. http://doi.org/10.1210/jc.2011-3018

Moody, A. (2016). Health Survey for England 2015 Adult overweight and obesity Health Survey for England 2015: Adult overweight and obesity. Retrieved from http://content.digital.nhs.uk/catalogue/PUB22610/HSE2015-Adult-obe.pdf

Murdaugh, D. L., Cox, J. E., Cook Iii, E. W., & Weller, R. E. (2012). fMRI reactivity to high-calorie food pictures predicts short- and long-term outcome in a weight-loss program. *NeuroImage*, *59*, 2709–2721. http://doi.org/10.1016/j.neuroimage.2011.10.071

Murphy, K. G., & Bloom, S. R. (2006). Gut hormones and the regulation of energy homeostasis. *Nature*, *444*(7121), 854–9. http://doi.org/10.1038/nature05484

National Audit Office. (2015). *The management of adult diabetes services in the NHS: progress review. Department of Health and NHS England* (Vol. 489). Retrieved from https://www.nao.org.uk/wp-content/uploads/2015/10/The-management-of-adult-diabetes-services-in-the-NHS-progress-review.pdf

National Heart, Lung and Blood Institute . (1998). *Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: The*

evidence report. (NIH Publication No. 98-4083).

National Institute of Health and Clinical Excellence. (2014). Weight management: lifestyle services for overweight or obese adults | Guidance and guidelines | NICE. Retrieved May 15, 2017, from https://www.nice.org.uk/guidance/ph53

Naughton, P., McCarthy, M., & McCarthy, S. (2015). Acting to self-regulate unhealthy eating habits. An investigation into the effects of habit, hedonic hunger and self-regulation on sugar consumption from confectionery foods. *Food Quality and Preference*, *46*, 173–183. http://doi.org/10.1016/j.foodqual.2015.08.001

NICE. (2015). *Obesity prevention | Guidance and guidelines | NICE*. London: National Institute of Health and Clinical Excellence. Retrieved from https://www.nice.org.uk/guidance/cg43

Nijs, I. M. T., Muris, P., Euser, A. S., & Franken, I. H. A. (2010). Differences in attention to food and food intake between overweight/obese and normal-weight females under conditions of hunger and satiety. *Appetite*, *54*(2), 243–54. http://doi.org/10.1016/j.appet.2009.11.004

Nisbett, R. E. (1968). Determinants of food intake in obesity. *Science (New York, N.Y.)*, *159*(3820), 1254–5. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/5711760

O'Neil, P. M., Theim, K. R., Boeka, A., Johnson, G., & Miller-Kovach, K. (2012). Changes in weight control behaviors and hedonic hunger during a 12-week commercial weight loss program. *Eating Behaviors*, *13*(4), 354–60.

http://doi.org/10.1016/j.eatbeh.2012.06.002

Obese, overweight with risk factors: liraglutide (Saxenda) | Guidance and guidelines | NICE. (n.d.). Retrieved from https://www.nice.org.uk/advice/es14/chapter/Introduction-and-current-guidance

Obesity: identification, assessment and management | Guidance and guidelines | NICE. (2014). Retrieved from https://www.nice.org.uk/guidance/cg189/chapter/1-Recommendations

Ochner, C. N., Kwok, Y., Conceição, E., Pantazatos, S. P., Puma, L. M., Carnell, S., … Geliebter, A. (2011). Selective reduction in neural responses to high calorie foods following gastric bypass surgery. *Annals of Surgery*, *253*(3), 502–507. http://doi.org/10.1097/SLA.0b013e318203a289

Office for National Statistics. (2016). Population Estimates for UK, England and Wales, Scotland and Northern Ireland - Office for National Statistics. Retrieved May 15, 2017, from https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/mid2015

Papies, E. K. (2012). Goal priming in dieters: Recent insights and applications. *Current Obesity Reports*, *1*(2), 99–105. http://doi.org/10.1007/s13679-012-0009-8

Papies, E. K., Stroebe, W., & Aarts, H. (2009). Who likes it more? Restrained eaters' implicit attitudes towards food. *Appetite*, *53*(3), 279–87.

http://doi.org/10.1016/j.appet.2009.07.001

Park, R. J., Godier, L. R., & Cowdrey, F. A. (2014). Hungry for reward: How can neuroscience inform the development of treatment for Anorexia Nervosa? *Behaviour Research and Therapy*, *62*, 47–59. http://doi.org/10.1016/j.brat.2014.07.007

Parmenter, K., Waller, J., & Wardle, J. (2000). Demographic variation in nutrition knowledge in England. *Health Education Research*, *15*(2), 163–74. http://doi.org/10.1093/her/15.2.163

Perello, M., & Dickson, S. L. (2015). Ghrelin signalling on food reward: A salient link between the gut and the mesolimbic system. *Journal of Neuroendocrinology*, *27*(6), 424–434. http://doi.org/10.1111/jne.12236

Petersen, L., & Sørensen, T. I. A. (2011a). Studies based on the Danish Adoption Register: Schizophrenia, BMI, smoking, and mortality in perspective. *Scandinavian Journal of Public Health*, *39*(7), 191–195. http://doi.org/10.1177/1403494810396560

Petersen, L., & Sørensen, T. I. A. (2011b). The Danish Adoption Register. *Scandinavian Journal of Public Health*, *39*, 83–86. http://doi.org/10.1177/1403494810394714

Pinel, J. P. J., Assanand, S., & Lehman, D. R. (2000). Hunger, eating, and ill health. *American Psychologist*, *55*(10), 1105–1116. http://doi.org/10.1037/0003-066X.55.10.1105

Polivy, J., Coleman, J., & Herman, C. P. (2005). The effect of deprivation on food cravings and eating behavior in restrained and unrestrained eaters. *International Journal of Eating Disorders*, *38*(4), 301–309. http://doi.org/10.1002/eat.20195

Pories, W. J. (2008). Bariatric Surgery: Risks and Rewards. *The Journal of Clinical Endocrinology & Metabolism*, *93*(11), s89–s96. http://doi.org/10.1210/jc.2008-1641

Postrach, E., Aspalter, R., Elbelt, U., Koller, M., Longin, R., Schulzke, J.-D., & Valentini, L. (2013). Determinants of successful weight loss after using a commercial web-based weight reduction program for six months: cohort study. *Journal of Medical Internet Research*, *15*(10), e219. http://doi.org/10.2196/jmir.2648

Pothos, E. M., Calitri, R., Tapper, K., Brunstrom, J. M., & Rogers, P. J. (2009). Comparing measures of cognitive bias relating to eating behaviour. *Applied Cognitive Psychology*, *23*(7), 936–952. http://doi.org/10.1002/acp.1506

Price, M., Higgs, S., & Lee, M. (2015). Self-reported eating traits: Underlying components of food responsivity and dietary restriction are positively related to BMI. *Appetite*, *95*, 203–10. http://doi.org/10.1016/j.appet.2015.07.006

Puhl, R., & Brownell, K. D. (2001). Bias, Discrimination, and Obesity. *Obesity Research*, *9*(12), 788–805. http://doi.org/10.1038/oby.2001.108

Puhl, R. M., Andreyeva, T., & Brownell, K. D. (2008). Perceptions of weight discrimination: prevalence and comparison to race and gender discrimination

in America. *International Journal of Obesity*, *32*(6), 992–1000. http://doi.org/10.1038/ijo.2008.22

Puhl, R. M., & Heuer, C. A. (2009). The Stigma of Obesity: A Review and Update. *Obesity*, *17*(5), 941–964. http://doi.org/10.1038/oby.2008.636

Rejeski, W. J., Burdette, J., Burns, M., Morgan, A. R., Hayasaka, S., Norris, J., … Laurienti, P. J. (2012). Power of food moderates food craving, perceived control, and brain networks following a short-term post-absorptive state in older adults. *Appetite*, *58*(3), 806–13. http://doi.org/10.1016/j.appet.2012.01.025

Ribeiro, G., Santos, O., Camacho, M., Torres, S., Mucha-Vieira, F., Sampaio, D., … Oliveira-Maia, A. J. (2015). Translation, cultural adaptation and validation of the Power of Food Scale for use by adult populations in Portugal. *Acta Médica Portuguesa*, *28*(5), 575. http://doi.org/10.20344/amp.6517

Rigamonti, A. E., Piscitelli, F., Aveta, T., Agosti, F., De Col, A., Bini, S., … Sartorio, A. (2015). Anticipatory and consummatory effects of (hedonic) chocolate intake are associated with increased circulating levels of the orexigenic peptide ghrelin and endocannabinoids in obese adults. *Food & Nutrition Research*, *59*, 29678. http://doi.org/10.3402/fnr.v59.29678

Roberts, C. A., Christiansen, P., & Halford, J. C. G. (2017). Tailoring pharmacotherapy to specific eating behaviours in obesity: Can recommendations for personalised therapy be made from the current data? *Acta Diabetologica*, *54*(8), 715–725. http://doi.org/10.1007/s00592-017-0994-x

Roberts, R. E., Deleger, S., Strawbridge, W. J., & Kaplan, G. A. (2003). Prospective association between obesity and depression: evidence from the Alameda County Study. *International Journal of Obesity*, *27*(4), 514–521. http://doi.org/10.1038/sj.ijo.0802204

Robertson, C., Archibald, D., Avenell, A., Douglas, F., Hoddinott, P., Van Teijlingen, E., … Fowler, C. (2014). Systematic reviews of and integrated report on the quantitative, qualitative and economic evidence base for the management of obesity in men. *Health Technology Assessment,* *18*(35). http://doi.org/10.3310/hta18350

Robinson, E., Hardman, C. A., Halford, J. C., & Jones, A. (2015). Eating under observation: a systematic review and meta-analysis of the effect that heightened awareness of observation has on laboratory measured energy intake. *American Journal of Clinical Nutrition*, *102*(2), 324–337. http://doi.org/10.3945/ajcn.115.111195

Robinson, T. E., & Berridge, K. C. (1993). The neural basis of drug craving: an incentive-sensitization theory of addiction. *Brain Research. Brain Research Reviews*, *18*(3), 247–291. http://doi.org/10.1016/0165-0173(93)90013-P

Robinson, T. E., & Berridge, K. C. (2003). Addiction. *Annual Review of Psychology*, *54*(1), 25–53. http://doi.org/10.1146/annurev.psych.54.101601.145237

Rodger, D. E., McFetridge, J. G., & Price, E. (1950). The management of obesity. *Canadian Medical Association Journal*, *63*(3), 265–9. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15434763

Rollins, B. Y., Dearing, K. K., & Epstein, L. H. (2010). Delay discounting moderates the effect of food reinforcement on energy intake among non-obese women. *Appetite*, *55*(3), 420–425. http://doi.org/10.1016/j.appet.2010.07.014

Rubino, F. (2013). From Bariatric to Metabolic Surgery: Definition of a New Discipline and Implications for Clinical Practice. *Current Atherosclerosis Reports*, *15*(12), 369. http://doi.org/10.1007/s11883-013-0369-x

Salem, L., Jensen, C. C., & Flum, D. R. (2005). Are bariatric surgical outcomes worth their cost? A systematic review. *Journal of the American College of Surgeons*, *200*(2), 270–8. http://doi.org/10.1016/j.jamcollsurg.2004.09.045

Santos, I., Sniehotta, F. F., Marques, M. M., Carraça, E. V., & Teixeira, P. J. (2017). Prevalence of personal weight control attempts in adults: a systematic review and meta-analysis. *Obesity Reviews*, *18*(1), 32–50. http://doi.org/10.1111/obr.12466

Sarwer, D. B., Thompson, J. K., & Cash, T. F. (2005). Body Image and Obesity in Adulthood. *Psychiatric Clinics of North America*, *28*(1), 69–87. http://doi.org/10.1016/j.psc.2004.09.002

Savage, J. S., Hoffman, L., & Birch, L. L. (2009). Dieting, restraint, and disinhibition predict women's weight change over 6 y. *American Journal of Clinical Nutrition*, *90*(1), 33–40. http://doi.org/10.3945/ajcn.2008.26558

Schachter, S., & Gross, L. P. (1968). Manipulated time and eating behaviour. *Journal of Personality and Social Psychology*, *10*(2), 98–106. Retrieved from

https://pdfs.semanticscholar.org/4ffc/88ae46ce83b15ad760572f980a6ca12e009
7.pdf

Schäfer E., L., & Jansson, M. (2008). Obesogenic environments – aspects on measurement and indicators. *Public Health Nutrition*, 1. http://doi.org/10.1017/S1368980008002450

Schmier, J. K., Jones, M. L., & Halpern, M. T. (2006). Cost of obesity in the workplace. *Scandinavian Journal of Work, Environment & Health*, *32*(1), 5–11. http://doi.org/10.5271/sjweh.970

Scholtz, S., Miras, A. D., Chhina, N., Prechtl, C. G., Sleeth, M. L., Daud, N. M., … Goldstone, A. P. (2014). Obese patients after gastric bypass surgery have lower brain-hedonic responses to food than after gastric banding. *Gut*, *63*(6), 891–902. http://doi.org/10.1136/gutjnl-2013-305008

Schultes, B., Ernst, B., Wilms, B., Thurnheer, M., & Hallschmid, M. (2010). Hedonic hunger is increased in severely obese patients and is reduced after gastric bypass surgery. *American Journal of Clinical Nutrition*, *92*(2), 277–283. http://doi.org/10.3945/ajcn.2009.29007

Schumacher, S. E., Kemps, E., & Tiggemann, M. (2016). Bias modification training can alter approach bias and chocolate consumption. *Appetite*, *96*, 219–224. http://doi.org/10.1016/j.appet.2015.09.014

Schüz, B., Schüz, N., & Ferguson, S. G. (2015). It's the power of food: individual differences in food cue responsiveness and snacking in everyday life. *The*

International Journal of Behavioral Nutrition and Physical Activity, *12*(1), 149. http://doi.org/10.1186/s12966-015-0312-3

Schvey, N. A., Puhl, R. M., & Brownell, K. D. (2011). The Impact of Weight Stigma on Caloric Consumption. *Obesity*, *19*(10), 1957–1962. http://doi.org/10.1038/oby.2011.204

Schyns, G., Roefs, A., Mulkens, S., & Jansen, A. (2016). Expectancy violation, reduction of food cue reactivity and less eating in the absence of hunger after one food cue exposure session for overweight and obese women. *Behaviour Research and Therapy*, *76*, 57–64. http://doi.org/10.1016/j.brat.2015.11.007

Shank, L. M. (2013). *The relation of hedonic hunger, hunger state, and food exposure to executive control, attentional focus bias, and heart rate variability* (M.Sc. thesis). Drexel University, USA. Retrieved from http://gradworks.umi.com/15/40/1540750.html

Shawky, R. M., & Sadik, D. I. (2012). Genetics of obesity. *Egyptian Journal of Medical Human Genetics*, *13*(1), 11–17. http://doi.org/10.1016/j.ejmhg.2011.08.005

Simon, G. E., Von Korff, M., Saunders, K., Miglioretti, D. L., Crane, P. K., van Belle, G., & Kessler, R. C. (2006). Association Between Obesity and Psychiatric Disorders in the US Adult Population. *Archives of General Psychiatry*, *63*(7), 824. http://doi.org/10.1001/archpsyc.63.7.824

Singh, M. (2014). Mood, food, and obesity. *Frontiers in Psychology*, *5*, 925. http://doi.org/10.3389/fpsyg.2014.00925

Sjöström, L., Narbro, K., Sjöström, C. D., Karason, K., Larsson, B., Wedel, H., … Carlsson, L. M. S. (2007). Effects of Bariatric Surgery on Mortality in Swedish Obese Subjects. *New England Journal of Medicine*, *357*(8), 741–752. http://doi.org/10.1056/NEJMoa066254

Slimming World. (n.d.-a). About Slimming World. Retrieved August 29, 2017, from http://www.slimmingworld.co.uk/about-us/about-slimming-world.aspx

Slimming World. (n.d.-b). What is Slimming World on Referral? Retrieved August 29, 2017, from http://www.slimmingworld.co.uk/health/swor/what-is-swor.aspx

Sobal, J., & Stunkard, A. J. (1989). Socioeconomic status and obesity: A review of the literature. *Psychological Bulletin*, *105*(2), 260–275. http://doi.org/10.1037/0033-2909.105.2.260

Sobell, L. C., & Sobell, M. B. (1992). Timeline Follow-Back. In *Measuring Alcohol Consumption* (pp. 41–72). Totowa, NJ: Humana Press. http://doi.org/10.1007/978-1-4612-0357-5_3

Inquisit (version 4, 2014). Seattle, WA: Millisecond Software.

Sooman, A., Macintyre, S., & Anderson, A. (1993). Scotland's health--a more difficult challenge for some? The price and availability of healthy foods in socially contrasting localities in the west of Scotland. *Health Bulletin*, *51*(5), 276–84. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8225953

Sørensen, T. I. A., & Stunkard, A. J. (1993). Does obesity run in families because of genes?. *Acta Psychiatrica Scandinavica*, *87*(S370), 67–72.

http://doi.org/10.1111/j.1600-0447.1993.tb05363.x

Stang, A. (2011). Randomized controlled trials-an indispensible part of clinical research. *Deutsches Arzteblatt International*, *108*(39), 661–2. http://doi.org/10.3238/arztebl.2011.0661

Stice, E., Fisher, M., & Lowe, M. R. (2004). Are dietary restraint scales valid measures of acute dietary restriction? Unobtrusive observational data suggest not. *Psychological Assessment*, *16*(1), 51–9. http://doi.org/10.1037/1040-3590.16.1.51

Stice, E., Shaw, H., Burton, E., & Wade, E. (2006). Dissonance and healthy weight eating disorder prevention programs: a randomized efficacy trial. *Journal of Consulting and Clinical Psychology*, *74*(2), 263–75. http://doi.org/10.1037/0022-006X.74.2.263

Stice, E., Yokum, S., Blum, K., & Bohon, C. (2010). Weight gain is associated with reduced striatal response to palatable food. *Journal of Neuroscience*, *30*(39). Retrieved from http://www.jneurosci.org/content/30/39/13105.short

Stoeckel, L. E., Weller, R. E., Cook, E. W., Twieg, D. B., Knowlton, R. C., & Cox, J. E. (2008). Widespread reward-system activation in obese women in response to pictures of high-calorie foods. *NeuroImage*, *41*(2), 636–647. http://doi.org/10.1016/j.neuroimage.2008.02.031

Stok, F. M., De Vet, E., Wardle, J., Chu, M. T., De Wit, J., & De Ridder, D. T. D. (2014). Navigating the obesogenic environment: How psychological sensitivity to the

food environment and self-regulatory competence are associated with adolescent unhealthy snacking. *Eating Behaviors*, *17C*, 19–22. http://doi.org/10.1016/j.eatbeh.2014.12.003

Strack, F., & Deutsch, R. (2004). Reflective and Impulsive Determinants of Social Behavior. *Personality and Social Psychology Review*, *8*(3), 220–247. http://doi.org/10.1207/s15327957pspr0803_1

Stroebe, W., Papies, E. K., & Aarts, H. (2008). From Homeostatic to Hedonic Theories of Eating: Self-Regulatory Failure in Food-Rich Environments. *Applied Psychology*, *57*(s1), 172–193. http://doi.org/10.1111/j.1464-0597.2008.00360.x

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643–662. http://doi.org/10.1037/h0054651

Stubbs, R. J., Morris, L., Pallister, C., Horgan, G., & Lavin, J. H. (2015). Weight outcomes audit in 1.3 million adults during their first 3 months' attendance in a commercial weight management programme. *BMC Public Health*. http://doi.org/10.1186/s12889-015-2225-0

Stubbs, R. J., Pallister, C., Whybrow, S., Avery, A., & Lavin, J. (2011). Weight outcomes audit for 34,271 adults referred to a primary care/commercial weight management partnership scheme. *Obesity Facts*, *4*(2), 113–20. http://doi.org/10.1159/000327249

Stunkard, A. J., Sørensen, T. I. A., Hanis, C., Teasdale, T. W., Chakraborty, R., Schull, W. J., & Schulsinger, F. (1986). An Adoption Study of Human Obesity. *New England*

Journal of Medicine, *314*(4), 193–198. http://doi.org/10.1056/NEJM198601233140401

Stunkard, A. J., & Messick, S. (1985). The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *Journal of Psychosomatic Research*, *29*(1), 71–83. http://doi.org/10.1016/0022-3999(85)90010-8

Swanton, K. (2008). *Healthy Weight, Healthy Lives: a Cross-Government Strategy for England*. Retrieved from http://www.fph.org.uk/uploads/full_obesity_toolkit-1.pdf

Swinburn, B. A., Sacks, G., Hall, K. D., McPherson, K., Finegood, D. T., Moodie, M. L., & Gortmaker, S. L. (2011). The global obesity pandemic: shaped by global drivers and local environments. *The Lancet*, *378*(9793), 804–814. http://doi.org/10.1016/S0140-6736(11)60813-1

Swinburn, B., Egger, G., & Raza, F. (1999). Dissecting Obesogenic Environments: The Development and Application of a Framework for Identifying and Prioritizing Environmental Interventions for Obesity. *Preventive Medicine*, *29*(6), 563–570. http://doi.org/10.1006/pmed.1999.0585

Tapper, K., Pothos, E. M., & Lawrence, A. D. (2010). Feast your eyes: hunger and trait reward drive predict attentional bias for food cues. *Emotion*, *10*(6), 949–54. http://doi.org/10.1037/a0020305

Tedstone, A., Targett, V., Owtram, G., Pyne, V., Allen, R., Bathrellou, K., … Morgan, K. (2017). Sugar Reduction: Achieving the 20% A technical report outlining

progress to date, guidelines for industry, 2015 baseline levels in key foods and next steps. Retrieved from www.gov.uk/phe

Temple, J. L. (2013). The Role of Food Reinforcement in Food Selection, Energy Intake, and Diet Quality. In *Diet Quality* (pp. 115–125). New York, NY: Springer New York. http://doi.org/10.1007/978-1-4614-7315-2_8

Temple, J. L., & Epstein, L. H. (2012). Sensitization of food reinforcement is related to weight status and baseline food reinforcement. *International Journal of Obesity*, *36*(8), 1102–1107. http://doi.org/10.1038/ijo.2011.210

Tetley, A., Brunstrom, J., & Griffiths, P. (2009). Individual differences in food-cue reactivity. The role of BMI and everyday portion-size selections. *Appetite*, *52*(3), 614–620. http://doi.org/10.1016/j.appet.2009.02.005

Theim, K. R., Brown, J. D., Juarascio, A. S., Malcolm, R. R., & O'Neil, P. M. (2013). Relations of Hedonic Hunger and Behavioral Change to Weight Loss Among Adults in a Behavioral Weight Loss Program Utilizing Meal-Replacement Products. *Behavior Modification*, *37*(6), 790–805. http://doi.org/10.1177/0145445513501319

Thomas, E. A, Bechtell, J. L., Vestal, B. E., Johnson, S. L., Bessesen, D. H., Tregellas, J. R., & Cornier, M.-A. (2013). Eating-related behaviors and appetite during energy imbalance in obese-prone and obese-resistant individuals. *Appetite*, *65*, 96–102. http://doi.org/10.1016/j.appet.2013.01.015

Tordoff, M. G. (2002). Obesity by choice: the powerful influence of nutrient

availability on nutrient intake. *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology*, *282*(5). Retrieved from http://ajpregu.physiology.org.liverpool.idm.oclc.org/content/282/5/R1536

Tovey, M. (2017). Obesity and the public purse: Weighing up the true cost to the taxpayer. Retrieved from https://iea.org.uk/wp-content/uploads/2017/01/Obesity-and-the-Public-Purse-PDF.pdf

Tschöp, M., Smiley, D. L., & Heiman, M. L. (2000). Ghrelin induces adiposity in rodents. *Nature*, *407*(6806), 908–13. http://doi.org/10.1038/35038090

Ullrich, J., Ernst, B., Wilms, B., Thurnheer, M., Hallschmid, M., & Schultes, B. (2013). The Hedonic Drive to Consume Palatable Foods Appears to be Lower in Gastric Band Carriers than in Severely Obese Patients Who Have Not Undergone a Bariatric Surgery. *Obesity Surgery*, *23*(4), 474–479. http://doi.org/10.1007/s11695-012-0818-6

Ullrich, J., Ernst, B., Wilms, B., Thurnheer, M., & Schultes, B. (2013). Roux-en Y gastric bypass surgery reduces hedonic hunger and improves dietary habits in severely obese subjects. *Obesity Surgery*, *23*(1), 50–5. http://doi.org/10.1007/s11695-012-0754-5

Vainik, U., Neseliler, S., Konstabel, K., Fellows, L. K., & Dagher, A. (2015). Eating traits questionnaires as a continuum of a single concept. Uncontrolled eating. *Appetite*, *90*, 229–239. http://doi.org/10.1016/j.appet.2015.03.004

Vandenbroeck, P., Goossens, J., & Clemens, M. (2007a). *Foresight Tackling Obesities:*

Future Choices – Building the Obesity System Map. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file /295154/07-1179-obesity-building-system-map.pdf

Vartanian, L. R. (2015). Impression management and food intake. Current directions in research. *Appetite*, *86*, 74–80. http://doi.org/10.1016/j.appet.2014.08.021

Vartanian, L. R., Herman, C. P., & Wansink, B. (2008). Are we aware of the external factors that influence our food intake? *Health Psychology : Official Journal of the Division of Health Psychology, American Psychological Association*, *27*(5), 533–8. http://doi.org/10.1037/0278-6133.27.5.533

Vartanian, L. R., & Porter, A. M. (2016). Weight stigma and eating behavior: A review of the literature. *Appetite*, *102*, 3-14. http://doi.org/10.1016/j.appet.2016.01.034

Volkow, N. D., Wang, G.-J., Fowler, J. S., & Telang, F. (2008). Overlapping neuronal circuits in addiction and obesity: evidence of systems pathology. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *363*(1507), 3191–200. http://doi.org/10.1098/rstb.2008.0107

Volkow, N. D., Wang, G.-J., Telang, F., Fowler, J. S., Logan, J., Childress, A.-R., … Wong, C. (2006). Cocaine Cues and Dopamine in Dorsal Striatum: Mechanism of Craving in Cocaine Addiction. *Journal of Neuroscience*, *26*(24), 6583–6588. http://doi.org/10.1523/JNEUROSCI.1544-06.2006

Vukmirovic, M. (2015). The effects of food advertising on food-related behaviours and perceptions in adults: A review. *Food Research International*, *75*, 13–19.

http://doi.org/10.1016/j.foodres.2015.05.011

Wang, Y. C., McPherson, K., Marsh, T., Gortmaker, S. L., & Brown, M. (2011). Health and economic burden of the projected obesity trends in the USA and the UK. *The Lancet*, *378*(9793), 815–825. http://doi.org/10.1016/S0140-6736(11)60814-3

Wansink, B., Painter, J. E., & Lee, Y.-K. (2006). The office candy dish: proximity's influence on estimated and actual consumption. *International Journal of Obesity*, *30*(5), 871–875. http://doi.org/10.1038/sj.ijo.0803217

Wardle, J., & Griffith, J. (2001). Socioeconomic status and weight control practices in British adults. *Journal of Epidemiology and Community Health*, *55*(3), 185–90. http://doi.org/10.1136/jech.55.3.185

Weight Watchers. (n.d.-a). Weight Watchers Ireland | The New Science Bit. Retrieved May 15, 2017, from http://217.115.115.243/food/food-education/food-education-archive/the-new-science-bit.html

Weight Watchers. (n.d.-b). *Working with the NHS for effective weight management The Weight Watchers Referral Scheme Guidance for Health Service Managers*. *Committee on Medical Aspects of Food Policy*. Retrieved from https://www.weightwatchers.co.uk/images/2057/dynamic/articles/2010/02/WWRSA4Brochurecombined.pdf

Weight Watchers. (2016). 2016 Annual Report. Retrieved from http://www.weightwatchersinternational.com/Cache/1500097885.PDF?O=PDF&T=&Y=&D=&FID=1500097885&iid=4071814

Weight Watchers. (2017a). who_we_are | Weight Watchers UK. Retrieved May 15, 2017, from https://www.weightwatchers.com/uk/about-us/who-we-are

Werthmann, J., Field, M., Roefs, A., Nederkoorn, C., & Jansen, A. (2014a). Attention bias for chocolate increases chocolate consumption--an attention bias modification study. *Journal of Behavior Therapy and Experimental Psychiatry*, *45*(1), 136–43. http://doi.org/10.1016/j.jbtep.2013.09.009

Werthmann, J., Field, M., Roefs, A., Nederkoorn, C., & Jansen, A. (2014b). Attention bias for chocolate increases chocolate consumption - An attention bias modification study. *Journal of Behavior Therapy and Experimental Psychiatry*, *45*(1), 136–143. http://doi.org/10.1016/j.jbtep.2013.09.009

Werthmann, J., Jansen, A., & Roefs, A. (2014). Worry or craving? A selective review of evidence for food-related attention biases in obese individuals, eating-disorder patients, restrained eaters and healthy samples. *The Proceedings of the Nutrition Society*. http://doi.org/10.1017/S0029665114001451

Werthmann, J., Jansen, A., Vreugdenhil, A. C. E., Nederkoorn, C., Schyns, G., & Roefs, A. (2015). Food through the child's eye: An eye-tracking study on attentional bias for food in healthy-weight children and children with obesity. *Health Psychology*, *34*(12), 1123–32. http://doi.org/10.1037/hea0000225

Werthmann, J., Renner, F., Roefs, A., Huibers, M. J. H., Plumanns, L., Krott, N., & Jansen, A. (2014). Looking at food in sad mood: Do attention biases lead emotional eaters into overeating after a negative mood induction? *Eating Behaviors*, *15*(2). http://doi.org/10.1016/j.eatbeh.2014.02.001

Werthmann, J., Roefs, A., Nederkoorn, C., Mogg, K., Bradley, B. P., & Jansen, A. (2011). Can(not) take my eyes off it: attention bias for food in overweight participants. *Health Psychology*, *30*(5), 561–9. http://doi.org/10.1037/a0024291

Werthmann, J., Roefs, A., Nederkoorn, C., Mogg, K., Bradley, B. P., & Jansen, A. (2013). Attention bias for food is independent of restraint in healthy weight individuals-An eye tracking study. *Eating Behaviors*. http://doi.org/10.1016/j.eatbeh.2013.06.005

WHO (2017). Obesity and overweight. *WHO*. Retrieved from http://www.who.int/mediacentre/factsheets/fs311/en/

Wing, R. R. (2002). Behavioral weight control. In T. A. Wadden & A. J. Stunkard (Eds.), *Handbook of obesity treatment.* (pp. 301–316). New York, NY US: Guilford Press. Retrieved from http://search.ebscohost.com.ezproxy.liv.ac.uk/login.aspx?direct=true&db=psyh&AN=2002-00571-008&site=ehost-live&scope=site

Wing, R. R., & Phelan, S. (2005). Long-term weight loss maintenance. *The American Journal of Clinical Nutrition*, *82*(1 Suppl), 222S–225S. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16002825

Winter, S. R., Feig, E. H., Kounios, J., Erickson, B., Berkowitz, S., & Lowe, M. R. (2016). The relation of hedonic hunger and restrained eating to lateralized frontal activation. *Physiology & Behavior*, *163*, 64–69. http://doi.org/10.1016/j.physbeh.2016.04.050

Witt, A. A, & Lowe, M. R. (2014). Hedonic hunger and binge eating among women with eating disorders. *The International Journal of Eating Disorders*, *47*(3), 273–80. http://doi.org/10.1002/eat.22171

Witt, A. A, Raggio, G. a, Butryn, M. L., & Lowe, M. R. (2014). Do hunger and exposure to food affect scores on a measure of hedonic hunger? An experimental study. *Appetite*, *74*, 1–5. http://doi.org/10.1016/j.appet.2013.11.010

Wong, E. S., Wang, B. C. M., Alfonso-Cristancho, R., Flum, D. R., Sullivan, S. D., Garrison, L. P., & Arterburn, D. E. (2012). BMI trajectories among the severely obese: results from an electronic medical record population. *Obesity*, *20*(10), 2107–12. http://doi.org/10.1038/oby.2012.29

Wrigley, N. (2002). "Food Deserts" in British Cities: Policy Context and Research Priorities. *Urban Studies*, *39*(11), 2029–2040. http://doi.org/10.1080/0042098022000011344

Yanovski, S. Z., & Yanovski, J. A. (2014). Long-term drug treatment for obesity: a systematic and clinical review. *JAMA*, *311*(1), 74–86. http://doi.org/10.1001/jama.2013.281361

Yeomans, M. R., Blundell, J. E., & Leshem, M. (2004). Palatability: response to nutritional need or need-free stimulation of appetite? *British Journal of Nutrition*, *92*(S1), S3. http://doi.org/10.1079/BJN20041134

Yokum, S., Ng, J., & Stice, E. (2011). Attentional bias to food images associated with elevated weight and future weight gain: an fMRI study. *Obesity*, *19*(9), 1775–83.

http://doi.org/10.1038/oby.2011.168

Yoshikawa, T., Tanaka, M., Ishii, A., & Watanabe, Y. (2014). Suppressive responses by visual food cues in postprandial activities of insular cortex as revealed by magnetoencephalography. *Brain Research*, *1568*, 31–41. http://doi.org/10.1016/j.brainres.2014.04.021

Zeller, M. H., Reiter-Purtill, J., & Ramey, C. (2008). Negative peer perceptions of obese children in the classroom environment. *Obesity, 16*(4), 755–62. http://doi.org/10.1038/oby.2008.4

Fore*sight*
Obesity System Map
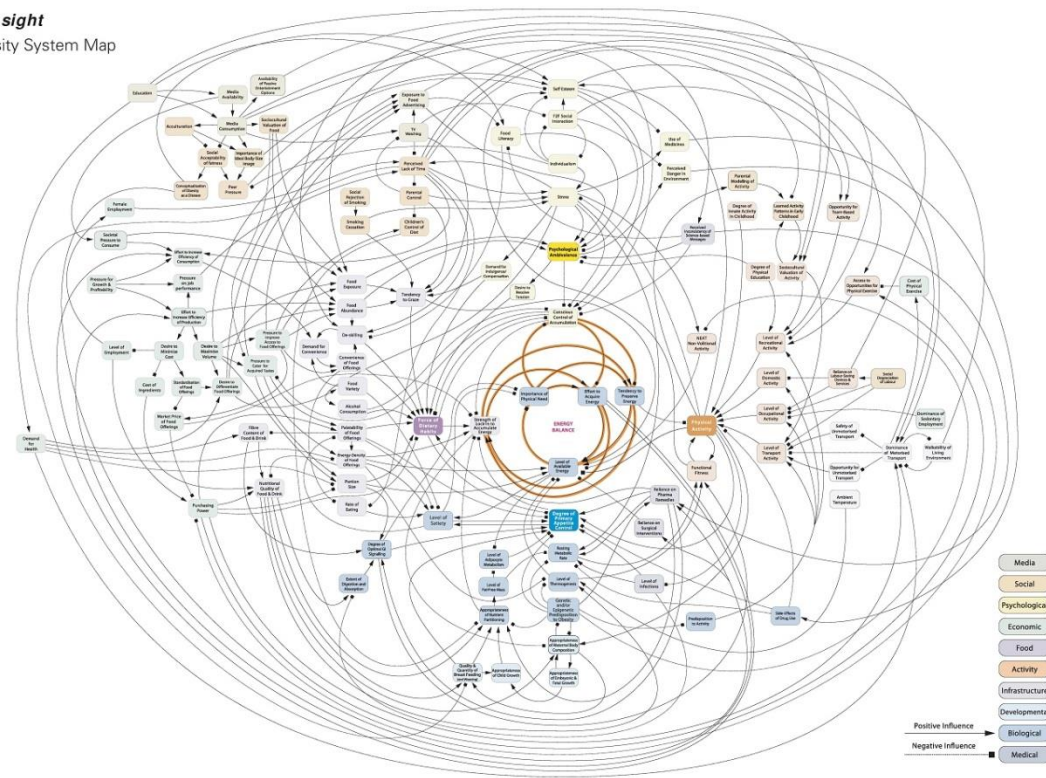
WRAP

Guided Self-Help Programme Script

- ➤ '*You have been assigned to what we call 'the guided self-help programme' arm of the study. This is a weight loss intervention designed by the research team. We will provide you with information and materials to help you design your own personalised diet plan. We will also meet with you and monitor your progress over the next 2 years.*

- ➤ '*We know that advice on weight loss can sometimes be overwhelming and difficult to absorb on the spot. So we would like to give you this leaflet to take away with you it has sections on;*
  - o *The benefits of losing weight*
  - o *How to design a weight loss plan that suits you*
  - o *Portion sizes and the components of a healthy diet*
  - o *How to change your behaviour'*

- ➤ **GO TO PAGE 5** of leaflet:
  '*This height/weight chart is a good way of setting yourself some goals. Your long-term goal should be to get into the 'Ideal Weight' section, but we recommend that you set yourself shorter-term goals to reach this ultimate aim. This booklet recommends aiming to lose 5-10 pounds in the first instance.'*

- ➤ **GO TO PAGE 9** of leaflet:
  '*This is a very useful tool to help you think about what you eat, it categorises foods into 5 groups, and shows you how much of each group you should eat'*

- ➤ **GO TO PAGE 10** of leaflet:
  '*You can see here how many portions you would need to eat to achieve a particular calorie intake per day'*

- ➤ **GO TO PAGE 13-16** of leaflet:
  '*Many people eat larger portions of food than they actually need. These are a useful guide to check your portions'*

- ➤ **GO TO PAGE 17** of leaflet:
  '*You can then use all this information to design your own eating plan, like this one here'. This means you can choose foods which best fit with your lifestyle, so the diet fits you rather than you trying to fit the diet*

- ➤ **GO TO PAGE 24** of leaflet:
  '*This section has some very good tips on how to change the way you think about your diet and how to change your current behaviour'*

- ➤ **GO TO PAGE 31** of leaflet:
  '*Finally, there is a progress chart where you can log your goals (e.g. 5 – 10 pounds) and your achievements'*

> *'Please take this home with you and have a good read. Keep it somewhere where you can refer to it easily, you might even want to cut out some of the charts or the Eatwell Plate and pin them on your fridge.'*

> *'Two other things that we know can help you to be successful are to weigh yourself regularly and to stay in touch. We encourage you to weigh yourself at home, but we will also check your weight at your follow-up visits for this study. Plus we will give you updates on your body composition (as we have just done), something which home-scales cannot usually do. It is really important that you attend these next visits, regardless of how you think you may be getting on with your diet. '*

Please confirm that you have completed the consultation with the participant by signing below:

Name of Research Team member   Date   Signature
(Please print)

Weight Loss Referrals for Adults in Primary Care (WRAP)

Participant Information Sheet (Part 1)

Study Coordinator: Emma Boyland

03303308093 (freephone)   wrap.study@liverpool.ac.uk

This leaflet is Part 1 and tells you about the purpose of the study and what will happen if you take part. There is more detail about how the study is conducted in Part 2. Please take time to read this information carefully. Talk to others about the study if you wish. Take time to decide whether or not you wish to take part. If you would like to ask some questions about the research you can contact your local study coordinator, Emma Boyland, without any obligation to participate.

What is the purpose of this study?

We want to find out which of three weight management programmes leads to most weight loss and makes the best use of NHS resources.

Why have I been chosen?

Your GP has searched her/his computer records to see who might be eligible to take part. Either you do not have a weight recorded or your last recorded weight suggests you might benefit from losing weight. Taking part in this study will not affect the usual care provided by your GP. You will still be able to receive other treatment from your GP during the study.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be asked to sign a consent form. You are still free to withdraw at any time without giving a reason. This will not affect the standard of usual care you receive at any clinic or medical practice, but the treatment that you receive as part of the study will cease. If you withdraw from the study you can also request that any data or other information relating to you are destroyed, and we will ensure that this happens.

What will happen to me if I take part?

You will come to the University of Liverpool to meet a member of the research team, who will explain the study and answer your questions. If you agree to take part, you will be randomly allocated to one of the three weight loss programmes. You will not have a choice about which weight loss programme you get and you will have to be prepared to try any of the three groups.

Group 1: If you are allocated to the 12 week Weight Watchers (WW) programme you will be expected to attend 12 free weekly WW group sessions. You will be able to choose meetings held at a time and location which suits you best. You will also be able to access WW internet resources for free for 16 weeks.
Group 2: If you are allocated to the 52 week Weight Watchers programme, you will be expected to attend WW free of charge for 12 months, with 12 months access to the WW internet resources.

Group 3: In the self-help programme, we will talk with you about your weight and give you a booklet with more information. It will be up to you to decide how to lose weight and follow the programme. We will also give you information about your weight and body composition.

Whichever group you are in, you will be asked to come to the University of Liverpool for measurement appointments. At the beginning, after 3, 12 and 24 months we will measure your height, weight, waist circumference, body fat level and blood pressure. We will ask you to fill in a short questionnaire at each visit.

If you are assigned to a Weight Watchers (WW) group in the study, we will collect data on your attendance and recorded weight. This is for research purposes only; we will not use this information to monitor you personally. The sharing of data between the study team and WW will be done using your unique code number; we will not use any personal identifying data information.

We also want to get a sample of your blood at the beginning and after 12 months. We will take sample of about 30ml (about 3 teaspoons full) in the first instance, then a smaller sample (no more than 15ml) at 12 months. By studying blood from a wide range of people, we can look at how the risk of heart disease or diabetes changes when people lose weight. With your consent, the results of your blood tests will be sent to yourself and your GP. We also plan to look at a range of genes which might affect your risk of CVD and diabetes, and your weight and response to weight loss interventions. The effects of these genes are very small and not yet well understood, and this research is at a very early stage. For this reason, we will not be giving you any information on your genes. You can still take part in the study if you do not want to give blood.

With your consent we will inform you and your GP of the results of your weight, fat mass and blood pressure measurements, and the results of your blood tests. Please note that samples from the study will not be processed immediately, so your results will only be available 6 – 12 months after they were taken.

To help us understand the health benefits of the three weight loss programmes, we would like to look at your medical notes at the end of the study. We will only do this with your consent. You can still take part in the study if you choose to opt out of having your medical notes reviewed.

We will ask for your consent to contact you through your GP during or after the study. This will help us to manage the study, so that if, for example if your phone number and address changes we can still communicate with you. It is your choice to respond to us or not. You can also choose to opt out of this part of the study if you want.

We also want to talk to some people about their experiences of trying to lose weight. We will not talk to everyone about this but, with your permission, we will approach you separately if we want to talk to you.

What do I have to do?

If you would like to participate in the study, and you have not already arranged your first visit, you should call or email your local study coordinator, Emma Boyland, on 03303308093 at the University of Liverpool. We will pay the costs of this call. If you already have an appointment for

your first visit, it should have been confirmed in the letter enclosed in this pack. We will send you a reminder of the date and time shortly before the visit.

What are the possible benefits of taking part?

You will receive advice and support to help you follow a healthy diet and to lose weight. Knowledge gained in this study will help our research into the prevention and treatment of obesity.

Will I be reimbursed for my time?

To compensate you for your time you will be paid £15 for attending each visit. We will also reimburse the cost of your travel to and from the University of Liverpool.

What are the possible risks and disadvantages of taking part?

If your blood measurements indicate you may be at increased risk of developing conditions such as heart disease or diabetes, we will inform you and your GP, provided you have given consent for this. With your consent, we will also inform your GP of any incidental findings in your blood results. As a result your GP may want to order more tests. A new diagnosis could affect your future insurance status (e.g. for life insurance or private medical insurance). Your GP will arrange any specific treatment you may need in the same way as usual. You will not be informed of any results from your genetic blood tests. This is because the results will not be clinically relevant. The results of the genetic analysis will be anonymised. However, before participating, you should consider the effect (although unlikely) that this might have on any insurance you have, and seek advice if necessary.

What happens when the research study stops?

After the study, you will be able to choose whether or not you continue trying to lose weight and will be free to choose any treatment you wish. We will not be able to continue to provide free access to Weight Watchers or other programmes after the study has ended.

What will happen if anything goes wrong?

Any complaints you have will be fully investigated. If you have a concern or complaint about any aspect of this project, please speak to your local study coordinator Emma Boyland who will try to answer your query. If you remain unhappy and wish to complain formally, details of our complaints procedure can be found in Part 2.

Will my taking part in this research study be kept confidential?

Yes. All information that is collected about you during the course of the research will be kept strictly confidential. The details are included in Part 2.

What will happen to the results?

The overall results may be presented at scientific meetings or published in a scientific journal. You will not be identified in any of these presentations or publications. We will send you a summary of the results when the study is completed and will be happy to discuss the results with you. Details are included in Part 2.

Weight Loss Referrals for Adults in Primary Care (WRAP)

Participant Information Sheet (Part 2)

Study Coordinator: Emma Boyland

03303308093 (free phone)   wrap.study@liverpool.ac.uk

This leaflet is Part 2; it will give you information on factors such as confidentiality and data protection, communication with your GP, indemnity and compensation. It is important that you read and are happy with this along with Part 1 before agreeing to take part.

Who is organising and funding the study?

This study is being organised by the Diet and Obesity Research group at MRC HNR with the University of Liverpool and the University of Oxford. The study is funded by the Medical Research Council and the National Prevention Research Initiative (NPRI). The cost of the Weight Watchers programme is funded by Weight Watchers International.

Who has reviewed the study?

This study has been reviewed by the NPRI Scientific Committee, the research Review Board of MRC HNR and by Liverpool Central Local Research Ethics Committee.

Will my taking part in this study be kept confidential?

Any information that is collected about you during the course of the research will be kept strictly confidential and MRC HNR will be the custodian of the data. Any information about you that leaves The University of Liverpool or MRC HNR will have your name and address removed so that you cannot be recognised from it.

HNR has a standard confidentiality procedure for participants involved in research, which the University of Liverpool will be adhering to. This stipulates how personal information is collected, used, stored and disposed of during and following completion of research projects. Any information that is collected about you during the course of the project will be kept strictly confidential and secure in locked filing cabinets and/or electronic files on computers that have restricted access. Each participant is assigned a unique, linked anonymising code number that is used on all data collected during the research. This code number is used to identify data in place of personal information.

If you are assigned to a Weight Watchers (WW) group in the study, we will collect data on your attendance and recorded weight. This is for research purposes only; we will not use this information to monitor you personally. This sharing of data between the study team and WW will be done using your unique code number; we will not use any personal identifying data information.

Only the specified research team will have access to personal identifying data information. However, with your agreement, your GP will be notified of your study results and copies of these letters will also be provided to you.

With your consent we will gather some information from the NHS about your healthcare usage during the study; this is so that we can measure the effect of weight loss on general health. As with all the other data we collect about you, this information will be kept confidential.

MRC HNR maintains a central record of all research projects but this does not include personal information on participants. With your agreement we will store data for 20 years. With your consent, and with the appropriate research ethics approval, retained data may be used for future studies.

Involvement of your GP/clinician

With your permission, your GP will be notified that you are participating in this study.

What will happen if I don't want to carry on with the study?

If you decide to withdraw from the study, with your consent, samples and data obtained may be kept and used to contribute to study results or, with your consent, for future studies. However, should you request your samples and data to be destroyed along with any other information relating to you, we will ensure that this takes place.

What if there is a problem?

In the unlikely event that something should go wrong during the study, procedures will be stopped and a clinician may see you. Your involvement in the rest of the study may be stopped. Standard procedures are in place at the University of Liverpool for dealing with serious adverse events should they occur.

If you have any other problems, illnesses or concerns during the study you should discuss these with the principal investigator or a member of the study team at the University of Liverpool.

Complaints:

Any complaints you have about this study will be fully investigated. If you have a concern about any aspect of this study, you should speak with the local study coordinator; Emma Boyland, Tel 0151 794 1137 who will do their best to answer your questions. If you remain unhappy and wish to complain formally, you can contact the Principal Investigator; Amy Ahern, Tel 01223 426356 Amy.Ahern@mrc-hnr.cam.ac.uk.

Harm:

In the event that something does go wrong and you are harmed during the research study there are no special compensation arrangements. If you are harmed and this is due to someone's negligence then you may have grounds for legal action for compensation against the University of Liverpool but you may have to pay your legal costs. For research carried out at the University of Liverpool participants would be in the same position as if public liability insurance had been taken out.

What will happen to any samples I give?

Any samples that are collected at the University of Liverpool during the course of the project will be immediately packaged and securely delivered to

MRC HNR where it will be processed and kept in accordance with MRC HNR standard operating procedures. Prior to postage each participant is assigned a unique, linked anonymising code to be used to label all samples collected during the research. This code number is used to identify stored samples in place of personal information. Only the specified research team will have access to your samples. With your agreement we may store samples for up to 10 years and then they will be destroyed. With your consent, and with the appropriate research ethics approval, retained samples may be used for future studies.

What will happen to the study results?

The overall study results may be presented at scientific meetings or published in a scientific journal. You will not be identified in these presentations and publications. We will be happy to discuss the results with you at the end of the study.

Independent Advice

If you would like some independent advice about this study please contact your local Primary Care Trust Patient Advise Liaison Service (PALS) http://www.pals.nhs.uk/officemapsearch.aspx.

Appendix 4 – WRAP Consent Form

Weight-loss Referrals for Adults in Primary Care
C O N S E N T   F O R M

LREC Reference Number: 0363

Name of Lead Investigator: Dr. Amy Ahern

Participant ID: ☐ ☐ ☐ ☐ ☐

Please initial boxes.

1. I confirm that I have read and understand the information sheets
   dated 04/09/2012 (Version 2.1) for the above study and have had the
   opportunity to ask questions.

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

3. I consent to my general practitioner being notified of my participation
   in this research and to being informed of my results.

4. I consent to providing blood samples at the first visit and 12 month follow-up
   visit. I understand that the results of my blood tests will not be provided
   for up to 12 months after a sample is given. I understand that I do NOT
   have to give blood to participate in this study.

5. I give permission that data and samples taken as part of the protocol of this
   study may be stored and used in further research studies that have been
   approved by the appropriate Ethics Committee.

6. I give permission that my samples taken as part of this study may be
   analysed in another laboratory outside of MRC Human Nutrition Research.
   All samples will be made anonymous, and no personal information will be
   sent to another laboratory.

7. I give permission for some of the samples I give to be used for genetic
   research. This will provide information about how genes affect us when
   we are attempting to lose weight.

8. I understand that the purpose of the genetic research is not to provide
   information about my health and that none of the DNA tests will be done
   to look for medical conditions.

9. I understand that I cannot participate in this research if I am pregnant.
   I am not pregnant and will inform the research team if I become pregnant.

10. I understand that sections of any of my medical notes may be looked at by
    responsible members of the research team where it is relevant
    to my taking part in this research study. I give permission for these
    individuals to have access to my records.

11. I understand that Weight Watchers and the study team will share data
    but that this data will be anonymised and will not be used for any purposes
    other than research.

12. I am willing to be contacted again in the future beyond this study and any

potential follow-up from it. I understand that I am under no obligation to undergo any future additional tests and can withdraw this consent at any time by notifying the study team.

13. In the event that my contact details change, I am willing for the research team to attempt to contact me through my GP.

14. I understand that although this research is being performed in collaboration with a commercial company, I will not benefit financially if this research leads to the development of a new treatment or test.

15. I agree to take part in the above study.

_____   _____   _____
 Name of Volunteer   Date   Signature
(Please print)

_____   _____   _____
Name of Research Team Member Date   Signature

3 copies required: one original copy for researcher; one original copy for volunteer; one copy to be kept with volunteer's notes.

330

PoFScale

Please indicate the extent to which the following items describe you, by marking the box with a cross.

Use the following 1-5 scale for your responses.

1 = Don't agree at all

2 = Agree a little

3 = Agree somewhat

4 = agree

5 = strongly agree

	1	2	3	4	5
1. I find myself thinking about food even when I'm not physically hungry	1	2	3	4	5
2. I get more pleasure from eating than I do from almost anything else	1	2	3	4	5
3. If I see or smell a food I like, I get a powerful urge to have some	1	2	3	4	5
4. When I'm around a fattening food I love, it's hard to stop myself from at least tasting it	1	2	3	4	5
5. It's scary to think of the power that food has over me	1	2	3	4	5
6. When I know a delicious food is available, I can't help myself from thinking about having some	1	2	3	4	5
7. I love the taste of certain foods so much that I can't avoid eating them even if they're bad for me	1	2	3	4	5
8. Just before I taste a favourite food, I feel intense anticipation	1	2	3	4	5
9. When I eat delicious food I focus a lot on how good it tastes	1	2	3	4	5
10. Sometimes, when I'm doing everyday activities, I get an urge to eat 'out of the blue' (for no apparent reason)	1	2	3	4	5
11. I think I enjoy eating a lot more than most other people	1	2	3	4	5
12. Hearing someone describe a great meal makes me really want to have something to eat	1	2	3	4	5
13. It seems like I have food on my mind a lot	1	2	3	4	5
14. It's very important to me that the foods I eat are as delicious as possible	1	2	3	4	5
15. Before I eat a favourite food my mouth tends to flood with saliva	1	2	3	4	5

Dear [Patient name],

Weight-Loss Referrals for Adults in Primary Care (WRAP)

We are writing to inform you about the opportunity to participate in a research study which is aimed at helping people lose weight and maintain long-term weight loss.

Our records indicate that either you do not have a weight recorded or your last weight recorded suggests that you might benefit from losing weight.

This study is being led by a research team from the Medical Research Council, Human Nutrition Research unit, in partnership with the University of Oxford and the University of Liverpool. They want to find out which of three treatment programmes leads to the most weight loss and makes the best use of NHS resources.

The three treatments are:

1. Receiving some free advice and trying to lose weight by yourself *OR*
2. Going to Weight Watchers, free of charge, for 12 weeks *OR*
3. Going to Weight Watchers, free of charge, for 12 months

All programmes will take place in your local area. Taking part in this study is entirely voluntary and will not affect the usual care provided by your GP.

Whether or not you decide to take part, you will still be able to receive other treatment from your GP during the study.

If you are interested in taking-up the opportunity to participate in this study, please call 03303308093 (free from landlines and some mobiles[*]) and have a chat with the local study co-ordinator Emma Boyland. Alternatively, you can email wrap.study@liverpool.ac.uk. When you contact the study coordinator, they will ask you for your weight and height. This is to ensure that you are suitable for this study. It would be useful if you have these measurements to hand when you call or email. The study co-ordinator will then discuss the study with you in more detail, ask you some questions to find out if you are eligible to participate, and invite you to come into the research centre.

Considerable research has linked being overweight with an increased risk of developing major diseases, but there is also good evidence to suggest that moderate weight loss at any age can have a positive impact on reducing these risks.

We hope you will take the opportunity to take advantage of this new and exciting opportunity.

Yours sincerely

(Patients GP)

PROTECT PERSONAL

WRAP

Telephone Screening Questionnaire and Script

Questions in bold – official use only

Introduction

➢ '*Hello, thank you for calling. Were you invited to take part in this study by a letter from your GP?*'
YES (go to 3) / NO (go to 2)

➢ '*I'm sorry; this study is by GP referral only. May I ask how you found out about the study?*'
Details: ……………………………………………………………………………………………………

➢ Do you have a GP reference number? You will find it on the invite letter.
………………………………………………

➢ '*Has anyone else in your household received the same letter?*'
IF NO:

'*OK, if you find out that anyone else in your household has received the same letter please let us know.*'

GO TO 5 AND CONTINUE SCREENING AS NORMAL

IF YES:

'*Do you know if they are interested in taking part?*'

  ➢ IF DEFINITELY NO:
  '*OK. That's not a problem. If they change their minds, please could one of you let us know? The easiest way would be if they just mention that they live with someone else who is already in the study when they call us.*'

  ➢ IF DEFINATLEY YES:
  '*OK. Have they already called us?*'

  YES – '*OK, I will continue with your screening and from your address I will find out the second member of your household. If you are both eligible then I will contact you again to discuss how to proceed. It will not stop you, or the other member of your household from participating, but your participation may be slightly different from the other person in your household*.'

NO – '*OK, I will continue with your screening for now. When they do call us I will match your postcode with theirs. If you are both eligible then I will contact you again to discuss how to proceed, it will not stop you from participating, but your participation may be slightly different from the other person in your household.'*

DON'T KNOW – '*OK, I will continue with your screening for now. From your postcode I will find out if the second member of your household has already called or not. If you both turn out to be eligible then I will contact you again to discuss how to proceed, it will not stop you from participating, but your participation may be slightly different from the other person in your household.'*

GO TO 5 AND CONTINUE SCREENING AS NORMAL

IF DON'T KNOW:

'*OK. That's not a problem. I can use your address to find out if anyone from your household has already called, or if anyone calls in the future. I will let you know.'*

> GO TO 5 AND CONTINUE SCREENING AS NORMAL '*I would like to tell you a bit more about the study, then I will ask you a few questions to check that you are suitable to participate in this study, it should only take a few minutes. After which, you can ask me any questions that you have about the study.*
> '*In this study, we are trying to find out what kind of weight loss programme is most effective. There are three different programmes that we are testing (1) a 12 week Weight Watchers programme, (2) a 12 month Weight Watchers programme and (3) a self-help programme. If you decide to take part you will be allocated to one of the programmes and we will monitor your weight loss. You will need to follow whatever programme you are assigned to and attend 4 appointments at the University of Liverpool over a 2 year period'.*
> '*Are you interested in taking part?'*
> YES (go to 9) / NO (go to 8)

> '*Sorry to hear that, can I ask you why?'*
> Details:
> ……

> '*OK, great, I will need to ask you a few questions to make sure you are eligible for this study.*

A: DOB & BMI			
Date of Birth		Age	
Sex	Male Female		
What is your current weight?			Kg/Stone/Pounds
What is your current height?			Cm/Feet/Inches
Calculated BMI		Kg/m^2	

If BMI is > 28kg/m^2 – continue to section C

**If the participant does not know their measurements ask them if they would like to continue with the screening. Then, if they are eligible based on all the other criteria, you can ask them if they would like to find out their weight and
height and call or email back.**

If the BMI is borderline e.g. 27 kg/m^2 and the participant has estimated the measurements, you can invite them to attend a visit (provided they are eligible), but you must warn them that if their BMI as measured in the clinic is below 28, they will be sent home.

B: Status		
Do you **have**, or have you **had** any of the following conditions?	**Yes**	**No**
1. Are you pregnant?		
2. Are you planning to become pregnant in the next 2 years?		
3. Have you ever had bariatric (obesity) surgery?		
4. Are you planning to have bariatric (obesity) surgery in the next 2 years?		
5. Are you currently following a weight loss programme*?		
e.g. Slimming World, W2GO, Weight Watchers, Rosemary Connelly, etc.		
Defined as a structured and prescribed programme to lose weight (not just a self-regulated diet).		
6. Have you participated in a weight loss programme in the last 3 months?		
If YES to 6, please give details below:		
7. When did you finish this programme?		
Details		

> *Inform the participant that this might make them ineligible for the study, check with the PI or study-coordinator before proceeding.*

C: Other Research & Medications	Yes	No
8. Are you currently participating in another research study?		
If YES What does this study involve?		
If the study involves weight loss of any kind or may confound any of the outcome measures, discuss with the Study Coordinator or Study Clinician before proceeding.		
9. Does the other research exclude the participant?		
10. Are you currently on any medications? (please list below)		
Please ask the participant to bring any prescriptions to their visit.		

D: Availability and Transport		
Would you be happy to:	Yes	No
1. Attend University of Liverpool on 4 occasions? *Mention reimbursed travel expenses, but only if a receipt is provided*		
If NO, ask the participant why they are not happy to attend the visits. Try to troubleshoot these issues by suggesting travel options and by scheduling appointments that are suited to the participant. Note that we will offer a small honorarium of £15 for their time at each visit and that all travel will be reimbursed.		
2. Have your weight, height, waist and body fat measured at each visit? *Note: for some of these measurements, shoes and socks will have to be removed.*		

3. Have a blood sample taken?		
Informal question: do you usually have any trouble giving blood samples?		
If YES to 3 4. Fast overnight?		
5. Do you have any preferred days to attend the unit?		
If YES to 5, please give days below:		

E: Eligibility	YES	NO	UNSURE
Is the participant eligible?			
If YES			
'You appear to be suitable for this study. Do you have any questions you would like to ask at this stage?' mention if BMI is borderline they may be ineligible *'What I would like to do next is send you some more information and book you in for your first visit'* on your 1st visit can you bring a list of your current medication *'I will need to ask you a few questions now. Firstly, can I take your personal details? This is so that we can contact you, these details will be kept confidential'* **CONTINUE TO SECTION F**			

If NO	YES	NO
'Would you like information about other studies at Kissileff lab, University of Liverpool or consider placing your name on our Volunteer Database?'		
If YES to volunteer database (above), information sent?		
Date information sent		
If UNSURE		
'I'm sorry, but from the information that you have given me, I am uncertain of your eligibility, I would like to check with a clinician/trial manager/advisor and get back to you.'		

F: Personal Details						
Title		Forename			Surname	
Address						
Postcode						
Telephone	Day			Evening		
Mobile				Happy to receive texts?		
Best time to phone						
Email						
Name of GP						
If the participant has NOT provided a GP reference number:						
GP Practice						
GP telephone number						
Date of appointment						
Time of appointment						

	YES	NO
Information Sheets sent?		
Date sent?		

G: Other Comments

--------------------- --
Investigator *(please print)*   Date *(dd/mm/yyyy)*   Signature

Data entered into database:

--------------------- --------------   ------------------
Investigator *(please print)*   Date *(dd/mm/yyyy)*   Signature

Medical History Questionnaire

Please complete the following:

Date of birth (DD/MM/YY): _____

Gender: Male / Female

Height: _____

Weight: _____

This questionnaire is designed to establish your suitability for this research project. The questionnaire will not be used as part of the study data but will be kept separately and securely for your wellbeing during the study.

Some of the questions ask about personal information. If you do not wish to answer please let the researcher know. All information taken is confidential.

Please answer as honestly as possible.

1.   Are you taking or using any medicine or any other drug, either from your doctor or on your own accord?
Yes / No
If so, please list the items below:
_____

2.   Are there any foods you don't eat?
Yes / No
If so, please state what and why.
_____

_____

3.   Are you allergic to anything that you are aware of?
Yes / No

4.   The following foods have been known to cause allergies. Have you ever consumed these foods **AND** had an allergic reaction to them?

	Previously Consumed	Allergic Reaction
Peanuts	Yes / No	Yes / No
Nuts	Yes / No	Yes / No
Dairy produce	Yes / No	Yes / No
Seeds	Yes / No	Yes / No
Eggs	Yes / No	Yes / No
Fish	Yes / No	Yes / No
Shellfish	Yes / No	Yes / No
Soy(a)	Yes / No	Yes / No
Celery	Yes / No	Yes / No
Mustard	Yes / No	Yes / No
Strawberries	Yes / No	Yes / No
Cherries	Yes / No	Yes / No
Kiwifruit	Yes / No	Yes / No
Pulses	Yes / No	Yes / No
	Previously Consumed	Allergic Reaction
Foods containing **sulphur dioxide/sulphites sulphites** (eg soft drinks, white wine, dried fruits	Yes / No	Yes / No
Foods containing **lupin** (eg, seeded bread, pastries)	Yes / No	Yes / No
Foods containing **gluten** (eg wheat, rye, barley, oats)	Yes / No	Yes / No
Foods containing **lactose** (eg milk, cheese, ice-cream)	Yes / No	Yes / No
Foods containing **salicylates** (eg dried plums, dates, figs, mushrooms)	Yes / No	Yes / No

6.   Are there any foods which make your mouth, lips or throat tingle?

Yes / No

7.   Have you ever suffered from anaphylaxis or anaphylactic shock?

Yes / No

8.   Did you suffer from severe childhood allergies?

Yes / No

For Office use only

Date Screened	**All questions answered**
	Yes / No
Researcher (print name)	**Suitable for study**
	Yes / No
Researcher signature	

Chocolate Consumption Questionnaire

Please think back over the last seven days and try to remember how much chocolate you have eaten on each day. You can record this in the spaces below. Please try to be as accurate as possible and describe the size, amount and type of product you ate. For example, one standard single bar of Cadbury Dairy Milk per day, two chocolate chip cookies, one piece of chocolate cake etc. It may help to think back to events of the previous seven days to help you remember.

Day 1 Yesterday	
Day 2 The day before yesterday	
Day 3	
Day 4	
Day 5	
Day 6	
Day 7	

UNIVERSITY OF
LIVERPOOL

PARTICIPANT INFORMATION SHEET
Study Title: **Attention and taste perception**
(Ethics reference: IPHS-1415-LB-280)

You are being invited to participate in a research study. Before you decide whether to participate, it is important that you understand why the research is being done and what it will involve. Please take time to read the following information carefully and feel free to ask us if you would like more information or if there is anything that you do not understand. Please also feel free to discuss this with your friends, relatives and GP if you wish. We would like to stress that you do not have to accept this invitation and should only agree to take part if you want to.

Thank you for reading this.

What is the purpose of the study?

We are interested in the way that people look at pictures of foods and if this influences their taste perception.

Why have I been invited to take part?

We are looking for *females* who:
- Are aged 18-55 years old
- Have a BMI above 24.9 kg/m^2 (we will check this for you)
- Are **not** dieting (not following a structured weight loss programme, e.g. Weight Watchers, Atkins, Slimming World, NHS Weight Loss Group etc).
- Are not currently pregnant
- Are fluent English speakers
- Have 20/20 or corrected (not glasses) to 20/20 vision
- Have **no** food allergies or intolerances
- **Like and regularly consume** cake, chocolate, biscuits, potato crisps and chips
- Score within a certain range on a questionnaire that assesses our reaction to food (we will check this for you)
- Are not currently taking part in another appetite-based research study
- Are willing to complete a short computer task on their home/work computer on 5 days out of 7
- Are willing to attend two laboratory testing sessions

If you meet these criteria, then you may be eligible to take part.

Do I have to take part?

You are under no obligation to take part in this study; it is completely your choice. If you do decide to take part you will be able to retain this information sheet and a copy of the consent form. If you do decide to take part, you are free to withdraw at any time and without giving a reason, without incurring a disadvantage.

What will happen if I take part?

If you agree to take part in the study, we will ask you to complete an online screening questionnaire (approximately 5-10 minutes), participate in two laboratory sessions approximately one week apart and complete an online follow-up questionnaire one week after the second session. The first online questionnaire is a screening questionnaire and assesses your eligibility for the study. If you are eligible to take part we will contact you to arrange the first of two lab sessions. During the lab sessions, we will ask you to complete:

- some tasks on a computer whilst your eye-movements are recorded
- some paper questionnaires
  - a taste test of **up to two** of the following snack foods: **cake, chocolate, biscuits, potato crisps and chips**. Foods will be selected at random.

  - We will also ask you to write down how much of one of the five possible snack foods listed above you have eaten over the last seven days. We will tell you which food this will be when you begin the study.
Finally, your height and weight will be measured.

The laboratory sessions will each last approximately 30-45 minutes. You will be asked not to eat anything in the **two hours** before your appointment. Appointments will take place seven days apart and in the Kissileff laboratory which is on the ground floor of the Eleanor Rathbone building (building number 106 on the University campus map).

You will also be asked to complete a short reaction time task on the internet in your own time, outside of the lab, on 5 separate occasions in the seven days between the lab sessions. This needs to be done on a laptop/desktop computer and will take approximately 8 minutes to complete.

One week after you attend the second session we will ask you to complete an online follow-up questionnaire (approximately 5 minutes) about snack foods that you have eaten since your last laboratory appointment. This will take approximately five minutes. Paper copies of online questionnaires will be available if preferred.

Are there any risks in taking part, or benefits from participation?

As you will be asked to taste food products, it is important that we ensure you do not have any food allergies or intolerances. You will be asked about this in the screening questionnaire and, if you are invited to the laboratory, this will be checked at the first laboratory session.The experimenter will also verbally check this with you before starting the experiment. Please ensure that you inform them if you have ever experienced a food intolerance/allergy. If you wish to discuss this with the project supervisor prior to meeting with the experimenter then please contact Dr Emma Boyland using the details given below. There are no other anticipated risks to you if you take part. You will be reimbursed with £20 Amazon online shopping vouchers for your time and inconvenience upon completion of all study tasks. Psychology students taking part in the study under the department's EPR scheme will receive course credit for their participation (1 point per 10 minutes participation to a maximum of 12 points). In addition to this, if a participant completes all of the study procedures and also each time participants complete the internet task they will be entered in to a prize draw (maximum six entries per participant) to win an additional £20 online shopping voucher once the study is completed. Participants who complete the internet task five times will therefore be have five entries in to the prize draw, plus up to one additional entry for completing all of the study procedures.

Will my participation be kept confidential, and what will happen to the results?

All the information collected about you during the course of the research will be kept strictly confidential. Any information about you will not be disclosed to anyone.

During the screening questionnaire you will only be asked to provide an email address so we can contact you if you are eligible to take part in the study. This information will not be linked to any other data you provide during the study and will be used for screening purposes only. As soon as you have finished the study, all of the information you provide will be identified only by a participant number, you will not be identified by name.

Completed questionnaires will be stored in a locked filing cabinet in the PI's office for up to 7 years, after which they will be destroyed. All computer data will be identified by random participant number only, and will be stored in a password protected file on a computer located on the University campus. All procedures for handling and storing data will comply with the Data Protection Act 1998.

We intend to publish the results from this study in a scientific journal and they will also be included in Bethan Mead's PhD thesis. However, any information which you provide will be stored completely anonymously (with a random number), and you will not be identified in any publication or report resulting from the study.

What if I am unhappy, or there is a problem?

If you are unhappy at any point in the study, or if there is a problem, please tell the researcher or let us know by contacting the project supervisor Dr Emma Boyland at the address or phone number below. If you remain unhappy or have a complaint which you feel you cannot come to us with then you should contact the Research Governance Officer at the University, on 0151 794 8290 or via email at ethics@liv.ac.uk. The RGO is in charge of making sure our research is done properly. When contacting the Research Governance Officer, please provide details of the name or description of the study (Investigating the link between attention and taste perception) so that it can be identified. Please tell us the names of the researcher(s) involved (Project Supervisor: Dr Emma Boyland), and the details of the complaint you wish to make.

Will my taking part be covered by an insurance scheme?

Participants taking part in any study that has been approved by the University of Liverpool are covered by the University's insurance scheme.

Who can I contact if I have further questions?

If you have any questions then please contact the project supervisor:

Dr Emma Boyland
Department of Psychological Sciences, University of Liverpool, Liverpool, L69 7ZA
Telephone: 0151 7941137
Email: e.boyland@liverpool.ac.uk

Visual Analogue Scales

INSTRUCTIONS FOR PARTICIPANTS:

Please read each question and then put a mark through the line that best represents your response.

Example Only

How **TIRED** do you feel **at this moment**?

Not at all
Tired ———————————————————————————— Very
Tired

How would you rate your GENERAL MOOD right now?

Very
Bad ———————————————————————————— Very
Good

How TIRED do you feel right now?

Drowsy
Sluggish ———————————————————————————— Alert
Fatigued Lively

How ANXIOUS do you feel right now?

Tense
Nervous ———————————————————————————— Relaxed
On Edge Calm

How HAPPY do you feel right now?

Sad
Gloomy ———————————————————————————— Happy
Miserable Cheerful
hearted Light-

How HUNGRY do you feel right now?

Not at all ————————————————————————————

Extremely

hungry

hungry

How CLEAR HEADED do you feel right now?

Dazed ———————————————————— Clear
Headed

How THIRSTY do you feel right now?

Not at all ————————————————
                                            Extremely
thirsty   thirsty

How RELAXED do you feel right now?

Not at all ————————————————
                                            Extremely
relaxed   relaxed

Please tell us what time you last ate: _____

Taste Test

Please consume as much or as little of the chocolate as you like in order to give your valid assessment for the questions used below. Circle your response for each item. You can eat all of the chocolate if you wish although you will not be given any additional chocolate if you finish it. You can sample the chocolate and complete all of the questions for at once, or you can sample the chocolate each time you answer a question.

How **smooth** was the Chocolate?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **sweet** was the Chocolate?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **tasty** was the Chocolate?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **bitter** was the Chocolate?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **strong tasting** was the Chocolate?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

                                                    10= Extremely.

How **hard** was the Chocolate?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

                                                    10= Extremely.

How **bland** was the Chocolate?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

                                                    10= Extremely.

How **light** was the Chocolate?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

                                                    10= Extremely.

Taste Test

Please consume as much or as little of the potato crisps as you like in order to give your valid assessment for the questions used below. Circle your response for each item. You can eat all of the potato crisps if you wish although you will not be given any additional potato crisps if you finish them. You can sample the potato crisps and complete all of the questions for at once, or you can sample the potato crisps each time you answer a question.

How **crunchy** were the potato crisps?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **salty** were the potato crisps?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **tasty** were the potato crisps?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **bitter** were the potato crisps?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **strong tasting** were the potato crisps?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **hard** were the potato crisps?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **bland** were the potato crisps?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

How **light** were the potato crisps?

0   1   2   3   4   5   6   7   8   9   10

0= Not at all

10= Extremely.

Appendix 14 – Example Visual Probe Task Stimuli from Chapter 4

Appendix 15 – Example Visual Probe Task Stimuli from Chapter 5

WRAP Food Cues Sub-Study

Study Overview Script

<u>Script applied to participants who are aged under 60 years and have consented to being informed of other studies relating to the WRAP trial</u>

<u>Please circle the participant's responses</u>

1. Introduction

"We are also running another study that is related to the WRAP trial. This study is separate to the main WRAP trial and you can choose whether or not to take part in this. The study is being run by Bethan Mead, a PhD student who works with us on the WRAP trial. The study looks at how people respond to information about food when they are taking part in a weight management programme. Would you be interested in finding our more about this study and what it involves?"

YES (go to **3**) / NO (go to **2**)

2. *That's OK then. Thank you for your time.*

3. Study overview

"We want to study how people respond to images of food before they begin a weight management programme and after they've been involved with a weight management programme for three months. We also want to look at how these responses are related to individual differences in appetite. Participants in the study are asked to complete some questionnaires and two computer tasks at a separate appointment before they attend their first Weight Watchers meeting and then again 3 months later. Would you like to take some information about the study away with you?"

YES (go to 5) / NO (go to 4)

4. *That's OK then. Thank you for your time.*

5. Participant Information Sheets – provide participant with the Participant Invitation Letter, Participant Information Sheet and Consent Form.

"These information sheets will tell you more about the study and what it involves. Bethan's contact details are in here in case you have any questions about the study. By taking this information with you, you are under no obligation to take part in this study. Bethan will give you a call in at least 24 hours after you've had a chance to read through these, to ask if you would be interested in taking part in the study or to give you some more information about it if you had any questions. You are still under no obligation to take part in the study and can say no when she calls if you wanted to. Would you be happy for her to give you a call after you have read through the information sheets?"

YES (go to 7) / NO (go to 6)

6.*That's not a problem. If you did read through and decided that you wanted to take part or ask a question about the study, you can still do so. Bethan's contact details are in these information sheets.*

7. *"Would you be happy for Bethan to use the telephone number we have on file for you for the WRAP trial?"*

YES (go to 9) / NO (go to 8 then 9)

8. *"Which number would you like her to call you on?"*

Record phone number here:

Name:

9. *"Thank you. Bethan will call you when you have had 24 hours to consider taking part in the study."*

Date:

Time:

Protect – Personal

Dear Participant,

Re: WRAP Food Cues Sub-Study

I am contacting you to ask if you would like to take part in a research study about the way people respond to food information when they are taking part in a weight management programme. We believe that investigating this could help us to understand why people respond differently to weight management programmes. Your contribution will be extremely valuable, whether or not you lose weight, or complete the programme.

I have included an Information Sheet that gives you further details about the research study. Please take time to read this and decide whether or not you would like to participate. If you do decide to participate you will receive £15 compensation for your time and you will be reimbursed for any travel expenses.

I will telephone you at least 24 hours after you receive this information to explain the study and give you the opportunity to ask questions. If you are willing to participate, I will ask you some questions to ensure that you meet the eligibility criteria for the study. You will find these criteria in the attached information sheet. If you meet these criteria I will arrange an appointment for you to take part in the study at a time and date that is convenient for you. You are under no obligation to take part in this study. If you have any questions in the meantime, please do not hesitate to contact me by telephone (0151 794 3056) or email at b.mead@liverpool.ac.uk.

Yours faithfully,

Bethan R. Mead
PhD Researcher
Institute of Psychology, Health and Society
University of Liverpool

Dr Emma Boyland
WRAP Study Coordinator
Lecturer
Institute of Psychology, Health and Society
University of Liverpool
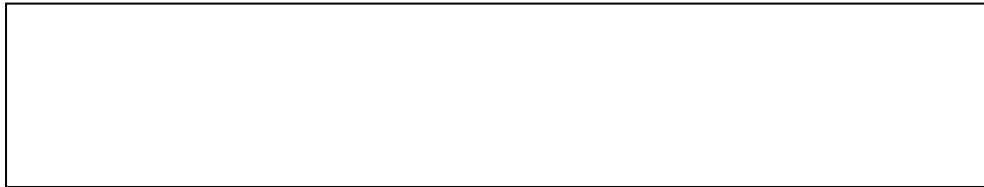
PARTICIPANT INFORMATION SHEET

Researchers: Bethan Mead, Emma Boyland, Jo Harrold, Jason Halford
Institute of Psychology, Health and Society, University of Liverpool
Principal Investigator: Amy Ahern – MRC Human Nutrition Research

[Tel: 0151 794 3056]   [Email:
b.mead@liverpool.ac.uk]

This sheet gives information on factors such as confidentiality, data protection, compensation, and publication etc. It is important that you read this information before agreeing to take part.

What is the purpose of this study?
We would like to learn about how people respond to images of food when they are participating in a weight management programme. For this purpose I am inviting you to attend two appointments as part of Food Cues sub-study.

Why have I been chosen?
Any individual participating in the Liverpool centre of the WRAP trial who has been allocated to the Commercial Programme Interventions, is under 60 years old and has consented to being contacted regarding future studies related to the WRAP trial is being invited to participate in this study. Our records indicate that you meet these criteria.

Am I eligible to take part?
Unfortunately, under some circumstances you may not be able to take part in this study. We will be unable to invite you to take part in this study if you meet any of the following criteria:
- Your age is above 60 years
- You do not have normal or corrected-to-normal (spectacles or contact lenses) vision
- You have a diagnosis of diabetes
- You are currently using antidepressants, or any other medications that control or are known to affect appetite and weight
- You are a vegetarian/vegan or have another dietary restriction
- You are unable to attend the first appointment for this study around the time of your first Weight Watchers meeting is scheduled to occur. Please be aware that we will **not** ask you to delay attending your first Weight Watchers meeting in order to take part in this sub-study.

Do I have to take part?
It is entirely up to you to decide whether or not to take part. Your decision will not affect your participation in the WRAP trial, and as such is separate to this. That is, if you do not wish to participate in this study, you will still be able to continue with the WRAP trial. If you do choose to take part, you will be asked to sign a consent form.

What do I have to do?

I will telephone you approximately 24 hours after you receive this information sheet to answer any questions or concerns you may have and to ask if you are willing to take part in the study. If you are willing to take part in the study I will ask you some questions to verify that you meet the eligibility criteria for the study. You may also contact me at [0151 794 3056] or b.mead@liverpool.ac.uk if you have any questions about the study.

What will happen to me if I take part?

If you are eligible to take part in this study I will arrange the first of two appointments for you to attend the University of Liverpool at a time and date that are convenient for you. The first appointment will be scheduled around the time you attend your first Weight Watchers meeting. The second appointment will occur approximately 3 months later.

At each appointment your body weight will be measured, you will complete some questionnaires, and you will complete two simple, computer tasks that assess the way people respond to images of food. The questionnaires assess aspects of people's thoughts and behaviour that may be relevant to appetite. The first computer task will assess how people pay attention to different types of images. If you do not wear spectacles or contact lenses to use a computer we will also measure your eye movements while you complete this task. The second computer task assesses how much people may like or want certain types of food. You do not need to be a regular computer user to complete these tasks.

After the first appointment you will be asked to return to the University to complete the same questionnaires and computerised tasks approximately 3 months later.

How much time will it take?

The appointments will take between 60 and 90 minutes each.

Will I be compensated for my time?

To compensate you for your time you will be given £15 for attending each appointment. We will also reimburse the cost of your travel to the appointment if travel receipts are provided.

Will taking part in the study benefit me?

There are no specific benefits to you if you take part. It is, however, an opportunity to help our research by helping us to understand how weight management programmes affect appetite and motivation for food, which may help us to develop more effective programmes.

What are the possible risks and disadvantages of taking part?

We are aware that appetite and weight management can be sensitive issues. You can choose not to complete any part of the study that you do not feel comfortable completing and there are no consequences associated with doing so. Some people find it uncomfortable to look at a computer for long periods of time. We try to keep these tasks as short as possible and will ask you take breaks between tasks. If you feel uncomfortable you can stop a task at any time and there are no consequences associated with doing so.

Can I withdraw from the study?

You can choose to withdraw from the study any time before, or during the study without giving a reason. If you choose to withdraw after the study has been completed, we will ask you if the study data we have obtained may be kept and used to contribute to the study results or, with your consent, for future studies.

However, should you request that your study data be destroyed, we will ensure that this takes place.

Will my taking part in this research study be kept confidential?
Yes. All information that is collected from you during the course of the study will be kept strictly confidential and the University of Liverpool will be the custodian of the data. All data will be stored at the Institute of Psychology, Health and Society at the University of Liverpool. The University of Liverpool has a standard confidentiality procedure for participants involved in research. This stipulates how personal information is collected, used, stored and disposed of during and following completion of research projects. During the study each participant will be assigned a unique anonymising code. It will only be possible to link you to the research data collected during the study by using this code. Only members of the research team named on this information sheet will be able to link personal identifying information to the data collected. With your agreement we will store data for 20 years. With your consent, and with the appropriate research ethics approval, retained data may be used for future studies.

All data collected, will be stored securely and kept strictly confidential. Paper copies will be stored under lock and key and electronic data will be stored on encrypted drives and/or computers that have restricted password protected access. All data is handled according to regulator standards and is GCP (Good Clinical Practice) compliant.

Only the research team named on this information sheet will have access to the anonymised data, with the exception of auditors of the funder, sponsor or regulatory inspectors if they decide to conduct an inspection to assess that the study is being properly conducted.

If at any time you decide to withdraw, we will request to keep any information we have already obtained from you for our final analysis. If you object to this, please let us know and we will destroy it.

Who is organizing the study?
This study is being carried out by the University of Liverpool in collaboration with MRC Human Nutrition Research as part of the WRAP trial. The WRAP trial is funded by the National Prevention Research Initiative and the cost of the Weight Watchers programme is covered by Weight Watchers International. This sub-study receives additional funding from a CASE studentship awarded to Bethan Mead by the University of Liverpool.

Who has reviewed the study?
The WRAP trial has been reviewed by the NPRI Scientific Committee, the research review board of MRC Human Nutrition Research, and by the Cambridge East Local Research Ethics Committee. This sub-study has received additional peer review from the University of Liverpool CASE Studentship Review Panel and Cambridge East Ethics Committee.

What if I have a complaint, wish to raise a concern, or require further information?
Any complaints you have about this study will be fully investigated. If you have a concern about any aspect of your participation, you can speak with the researcher, Bethan Mead (Tel: 0151 794 3056, email: b.mead@liverpool.ac.uk) or the Co-Investigator, Dr Emma Boyland (Tel: 0151 794 1137), email: e.boyland@liverpool.ac.uk), who will do their best to answer your questions. If you remain unhappy and wish to complain formally, you can contact the

Principal Investigator, Dr Amy Ahern, who can be contacted by telephone (01223 426356) or email (Amy.Ahern@mrc-hnr.cam.ac.uk).

If you would like some independent advice about this study please contact your local Primary Care Trust Patient Advise Liason Service (PALS) on 0800 279 2535. More information can be found at:
http://www.pals.nhs.uk/officemapsearch.aspx

What will happen to the results?
The overall study results may be presented at scientific meetings or published in a scientific journal. These findings will also form part of Bethan Mead's PhD thesis. You will not be identified in these presentations and publications.

WRAP Food Cues Sub-Study

CONSENT FORM

LREC Reference Number: 12/EE0363
Name of Researcher: Bethan R. Mead
Name of Co-investigators: Dr Emma Boyland, Dr Jo Harrold, Professor Jason Halford
Name of Principal Investigator: Dr. Amy Ahern
Participant ID: _____

Please initial the boxes

1. I confirm I have read and understand the Information Sheet (26/06/2013, version 1.2) and have had the opportunity to ask questions.

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

3. I understand that although this research is being performed in collaboration with a commercial company I will not benefit financially from this association.

4. I understand that my participation in this study is separate to my participation in the WRAP trial.

5. I give permission for the researchers to access data that I provide during the WRAP trial. I understand that this will be for the purpose of data analysis conducted as part of this study only and I will not be personally identifiable from this data.

6. I give permission that data taken as part of the protocol of this study may be stored and used in further research studies that have been approved by the appropriate Ethics Committee.

7. I agree to take part in this study.

Name of participant *(print)*   Signature   Date

Name of researcher *(print)*   Signature   Date

WRAP Food Cues Sub-Study

Telephone Screening Script

1. Introduce self and establish if the call is convenient. Arrange a call back if inconvenient.

2. *"At your appointment for the WRAP trial yesterday the researcher gave you some information about a study called "Food Cues Sub-Study". I'm calling to answer any questions you may have about the study and ask if you are interested in taking part"*

- ✓ YES or MORE INFORMATION NEEDED (go to 4) / NO (go to 3)

3. *That's OK then. Thank you for your time.* TERMINATE SCREENING

Study overview

4. *"I would like to give you an overview of the study and what it involves. Please feel free to ask me any questions that you may have."*

"In this study we are interested in the way people respond to information about food when they are taking part in a weight management programme, in this case, the WRAP trial. This study is separate to the WRAP trial and wouldn't affect your participation in the WRAP trial in any way."

"When people take part in the Food Cues Sub-Study study, I ask them to come in to the University of Liverpool for two appointments, spaced approximately 3 months apart. At both of these appointments I record their weight and would ask them to complete some questionnaires and computer tasks. The questionnaires look at some issues relating to how we think about food and our behaviour. The two computer tasks look at how we respond to information about food. The first one looks at how people respond to different types of images while they complete a simple attention task. The second one looks at how much people like or want different types of food. The first appointment would occur in the coming days, before you attend your first Weight Watchers meeting. The second one would be scheduled for approximately 3 months later. Would you be interested in taking part in this study?"

- ✓ YES or MORE INFORMATION NEEDED (go to 6) / NO (go to 5)

5. *That's OK then. Thank you for your time.* TERMINATE SCREENING

Eligibility

6. *"That's great, thank you. Before we go any further I need to ask you some questions to ensure that you are eligible to take part in the study. These questions relate to the eligibility criteria outlined in the information sheets that you received yesterday "*

- ✓ COMPLETE ELIGIBILITY CHECK USING CRITERIA TABLE AND RECORD OUTCOME OF EACH QUESTION. TERMINATE SCREENING IF A CRITERIA IS NOT MET

CRITERIA	RESPONSE	ELIGIBLE
a. DOB and Age		YES / NO
b. Do you have normal or corrected to normal vision? • If corrected to normal, do you wear glasses or contact lenses?		YES / NO
c. Are you diabetic?		YES / NO
d. Are you currently taking any anti-depressant medication?		YES / NO
e. Are you currently taking any medications that control or affect your appetite or weight?		YES / NO
f. Are you vegetarian, vegan or do you have any other dietary restriction?		YES / NO
g. Would you be able to attend an appointment to take part in this study before you plan to attend your first Weight Watchers meeting?		YES / NO
h. Is the participant eligible?		YES / NO

- ✓ 6h. NO (go to 7) / YES (go to 8)

7. I'm sorry, based on the information you have given me you do not appear to meet the eligibility criteria for this study and I will not be able to invite you to take part. This does not affect your participation in the WRAP trial in any way. TERMINATE SCREENING

8. *"You appear to be eligible for this study. Do you have any questions that you would like to ask me at this stage?"*

"What I would like to do now is book you in for your first visit"

DATE:

TIME:

Participants Required

Food Cues Study 2

We are looking for volunteers who are interested in losing weight to take part in a research study investigating our reactions to information about food during a weight management programme

You will be asked to attend 2 testing sessions, approximately 13 weeks apart, at the University of Liverpool. In between these appointments we will provide you with access to Weight Watchers meetings and online resources at no cost to you

Travel costs and reimbursement available

You are eligible to take part if

- You are aged between 18 and 60 years old
- Your Body Mass Index is above 28 kg/m^2 (you have a BMI above 28 kg/m^2. We will check this for you)
- You have normal vision (i.e. you are not partially sighted or you do not wear glasses. Contact lenses are ok.)
- You do not have a diagnosis of diabetes
- You are not currently using antidepressants or any other medications that control or are known to affect appetite and weight
- You are not vegetarian/vegan or have another dietary restriction
- You do not have a history of or have been diagnosed as having an eating disorder
- You are not currently pregnant or plan to become pregnant in the next 4 months
- You are a fluent English speaker
- You are not currently taking part in another research study that is related to appetite, diet, eating or weight
- You wish to attend Weight Watchers (free of charge) for 12 weeks
- You are willing to attend two laboratory testing sessions at the University of Liverpool

PARTICIPANT INFORMATION SHEET

Study Title: Food Cues Study 2

You are being invited to participate in a research study. Before you decide whether to participate, it is important that you understand why the research is being done and what it will involve. Please take time to read the following information carefully and feel free to ask us if you would like more information or if there is anything that you do not understand. Please also feel free to discuss this with your friends, relatives and GP if you wish. We would like to stress that you do not have to accept this invitation and should only agree to take part if you want to.
Thank you for reading this.

This sheet gives information on factors such as confidentiality, data protection, compensation, and publication etc. It is important that you read this information before agreeing to take part.

What is the purpose of this study?
We would like to learn about how people respond to images of food when they are participating in a weight management programme. For this purpose we are inviting you to attend two appointments as part of Food Cues sub-study.

Why have I been chosen?
We are looking for individuals who wish to take part in a 12-week weight management intervention.

Am I eligible to take part?
You are eligible to take part if
- You are aged between 18 and 60 years old.
- Your Body Mass Index is above 28 kg/m^2 (you have a BMI above 28 kg/m$^{2.}$ We will check this for you.)
- You have normal vision (i.e. you are not partially sighted or you do not wear glasses for computer use. Contact lenses are fine).
- You do not have a diagnosis of diabetes
- You are not currently using antidepressants or any other medications that control or are known to affect appetite and weight
- You are not vegetarian/vegan or have another dietary restriction
- You do not have a history of or have been diagnosed as having an eating disorder
- You are not currently pregnant or plan to become pregnant in the next 4 months
- You are a fluent English speaker
- You are not currently taking part in another research study that is related to appetite, diet, eating or weight.
- You wish to attend Weight Watchers (free of charge) for 12 weeks
- You are willing to attend two laboratory testing sessions at the University of Liverpool

Do I have to take part?

No. You are under no obligation to take part in this study; it is completely your choice and expressing an interest in learning more about the study does not oblige you to take part. If you do decide to take part you will be able to retain this information sheet and a copy of the consent form. If you do decide to take part, you are free to withdraw at any time and without giving a reason, without incurring a disadvantage. If you choose to withdraw after the study has been completed, we will ask you if the study data we have obtained may be kept and used to contribute to the study results or, with your consent, for future studies. However, should you request that your study data be destroyed, we will ensure that this takes place.

What do I have to do?
If you would like to take part in the study you can tell us this by either calling Bethan Mead on 0151 794 3056 or emailing b.mead@liverpool.ac.uk and telling us your name, telephone number and stating that you are interested in taking part in the Food Cues Study 2. We will then telephone you to discuss the study and ask you some questions to verify that you meet the eligibility criteria for the study. You may also contact us if you have any questions about the study or would like any more information before deciding if you would like to take part. Alternatively, if you have indicated that you would be happy for us to do so, we will contact you in the days after you receive this information sheet to ask if you have any questions about the study or if you would like to take part.

What will happen to me if I take part?
If you are eligible to take part in this study you will be invited to attend the first of two appointments at the University of Liverpool. In the time between the two appointments you will also be given access to Weight Watchers for 12 weeks, free of charge. When you attend the first appointment we will arrange a second appointment for approximately 13 weeks later.

At each appointment your height and body weight will be measured, you will complete some questionnaires, and you will complete two simple, computer-based tasks that assess the way people respond to images of food. The questionnaires assess aspects of people's thoughts and behaviour that may be relevant to appetite. The first computer task will assess how people pay attention to different types of images. We will also measure your eye movements while you complete this task. The second computer task assesses how much people may like or want certain types of food. You do not need to be a regular computer user to complete these tasks. The two appointments at the University of Liverpool will be carried out by Bethan Mead (PhD Researcher) or other study staff members, and they will take place in a quiet location at a time to suit you.

At your first appointment we will provide you with a pack containing vouchers to attend 12 Weight Watchers meetings, free of charge, a list of Weight Watchers meetings in the Liverpool area and an online code that will allow you free access to the Weight Watchers website for 12 weeks. The Weight Watchers vouchers will be valid for 13 weeks from the date of your first appointment at the University of Liverpool. This pack will be your weight management intervention. It is up to you to choose a Weight Watchers meeting that is most convenient for you to attend.

How much time will it take?
The appointments at the University of Liverpool will take approximately 60 minutes each. It will be up to you to use the Weight Watchers pack to follow the Weight Watchers programme in a way that is best for you.

Will I be compensated for my time?
To compensate you for your time you will be given £15 for attending each appointment. This will be payable at the end of the second appointment at the University of Liverpool.

At each appointment we will reimburse the cost of your travel to the appointment if travel receipts are provided.

Are there any risks in taking part, or benefits from participation?
There are no anticipated risks to you if you take part in the study. However, we are aware that appetite and weight management can be sensitive issues. You can choose not to complete any part of the study that you do not feel comfortable completing and there are no consequences associated with doing so. Some people find it uncomfortable to look at a computer for long periods of time. We try to keep these tasks as short as possible and will ask you take breaks between tasks. If you feel uncomfortable you can stop a task at any time and there are no consequences associated with doing so.

As we are looking for volunteers who are interested in attending a 12-week weight management programme, if you follow the Weight Watchers programme you may lose weight. Furthermore, taking part in the study is opportunity to help our research by helping us to understand how weight management programmes affect appetite and motivation for food, which may help us to develop more effective programmes.

Will my participation be kept confidential, and what will happen to the results?
All the information collected about you during the course of the research will be kept strictly confidential. Any information about you will not be disclosed to anyone. As soon as you have finished the study, all of the information you provide will be identified only by a participant number, you will not be identified by name. Only the researchers named on this information sheet will have access to the data.

Completed questionnaires will be stored in a locked filing cabinet in the PI's office for up to 7 years, after which they will be destroyed. All computer data will be identified by random participant number only, and will be stored in a password protected file on a computer located on the University campus. All procedures for handling and storing data will comply with the Data Protection Act 1998.

We intend to publish the results from this study in a scientific journal. However, any information which you provide will be stored completely anonymously (with a random number), and you will not be identified in any publication.

What if I am unhappy, or there is a problem?
If you are unhappy at any point in the study, or if there is a problem, please tell the researcher or let us know by contacting the principal investigator Dr Emma Boyland at the address or phone number below. If you remain unhappy or have a complaint which you feel you cannot come to us with then you should contact the Research Governance Officer at the University, on 0151 794 8290 or via email at ethics@liv.ac.uk. The RGO is in charge of making sure our research is done properly. When contacting the Research Governance Officer, please provide details of the name or description of the study (Food Cues Study 2) so that it can be identified. Please tell us the names of the researcher(s) involved (Principal Investigator: Dr Emma Boyland), and the details of the complaint you wish to make.

Who is organizing the study?
This study is being carried out by the University of Liverpool in collaboration with MRC Human Nutrition Research as part of the WRAP trial. The WRAP trial is funded by the National Prevention Research Initiative and the cost of the Weight Watchers programme is covered by Weight Watchers International. This sub-study receives additional funding from a CASE studentship awarded to Bethan Mead by the University of Liverpool.

Will my taking part be covered by an insurance scheme?
Participants taking part in any study that has been approved by the University of Liverpool are covered by the University's insurance scheme.

Who can I contact if I have further questions?
If you have any questions then please contact the principal investigator:
Dr Emma Boyland,
Department of Psychological Sciences, University of Liverpool, Liverpool, L69 7ZA
Telephone: 0151 7941137 / Email: eboyland@liverpool.ac.uk

Food Cues Study 2

Telephone Screening Script

1. Introduce self and establish if a call of approximately 5 minutes is convenient. Arrange a call back if inconvenient.

2. *"You recently contacted us because you were interested in taking part in the study 'Food Cues Study 2'. Would that still be the case? "*

   ✓ YES or MORE INFORMATION NEEDED (go to 4) / NO (go to 3)

3. *That's OK then. Thank you for your time.* TERMINATE SCREENING

4. *"That's great, thank you. I'd just like to go over what the study involves with you to make sure you are happy with it. Please feel free to ask me questions about this."*

"In this study we are interested in the way people respond to information about food when they are trying to lose weight in a 12 week Weight Watchers programme. You would need to attend two appointments at the University of Liverpool spaced approximately 13 weeks apart. At both of these appointments you would complete two short computer tasks and some questionnaires and have your height and weight measured. Your eye movements will be recorded while you complete one of the computer tasks

In between the two appointments at the university you would be able to attend Weight Watchers for 12 weeks at no cost to you. We would provide you with vouchers to attend 12 Weight Watchers meetings and a code that allows access to the Weight Watchers website for 12 weeks."

"Would you be interested in taking part in this study?"

   ✓ YES (go to 6) / NO (go to 5)

5. *That's OK then. Thank you for your time.* TERMINATE SCREENING

Eligibility 6. *"That's great, thank you. Before we go any further I need to ask you some questions to ensure that you are eligible to take part in the study. These questions relate to the eligibility criteria outlined in the information sheets that you received from us "*

   ✓ COMPLETE ELIGIBILITY CHECK USING CRITERIA TABLE AND RECORD OUTCOME OF EACH QUESTION. TERMINATE SCREENING IF A CRITERIA IS NOT MET

CRITERIA	RESPONSE	ELIGIBLE
a. Are you a fluent English speaker?		YES / NO
b. Would you be willing to attend Weight Watchers for 12 weeks using the referral pack provided by us?		YES / NO
c. Would you be willing to attend two testing sessions at the university of Liverpool, spaced approximately 13 weeks apart?		YES / NO
d. Age and Date of Birth		YES / NO
e. Do you have normal vision?		YES / NO
f. Are you diabetic?		YES / NO
g. Are you currently taking any medications that controls or affects your appetite or weight, such as antidepressant medication?		YES / NO
h. Are you vegetarian, vegan or do you have any other dietary restriction?		YES / NO
i. Do you have a current or previous diagnosis of an eating disorder?		YES / NO
j. Are you currently pregnant or planning to become pregnant in the next 4 months?		YES / NO
k. Are you currently taking part in any other research study? *(If yes, ask for details. Not eligible if related to appetite/diet/weight/eating)*		YES / NO
l. Is the participant eligible?		YES / NO

✓ 6l. NO (go to 7) / YES (go to 8)

7. *I'm sorry, based on the information you have given me you do not appear to meet the eligibility criteria for this study and I will not be able to invite you to take part.* TERMINATE SCREENING

8. *"You appear to be eligible for this study. Do you have any questions that you would like to ask me at this stage?"*

"What I would like to do now is book you in for your first visit"

DATE:

TIME:

UNIVERSITY OF
LIVERPOOL

CONSENT FORM

Title of Research Project: Food Cues Study 2

Researchers: Bethan Mead, Dr Emma Boyland, Dr Joanne Harrold, Professor Jason Halford, Dr Amy Ahern.

Please initial box

1. I confirm that I have read and have understood the information sheet dated 01/04/14 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 in order to take part in the study, I should meet the criteria outlined in the section "Am I eligible to take part?" in the attached information sheet.

3. I understand that if I agree to take part, I will be asked to take part in a two experimental sessions and a 12-week Weight Watchers programme. During the experimental sessions, I will fill out some questionnaires, and complete some tests on a computer while my eye movements are recorded.

4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected.

5. I understand that, under the Data Protection Act, I can at any time ask for access to the information I provide and I can also request the destruction of that information if I wish. In addition, I understand that none of my personal details will be recorded, and that my responses are anonymous.

6. I agree to take part in the above study.

_____   _____   _____

Participant Name   Date   Signature

_____   _____   _____

Researcher   Date   Signature

Principal Investigator
Dr Emma Boyland
Department of Psychological Sciences,
University of Liverpool, Liverpool, L69 7ZA
Telephone: 0151 7941137
Email: eboyland@liverpool.ac.uk

Student Researcher
Bethan Mead (PhD Researcher)
Department of Psychological Sciences,
University of Liverpool, Liverpool, L69 7ZA
Telephone: 0151 7943056
Email: b.mead@liverpool.ac.uk

Female participants required for a study of

attention and taste perception

Researchers in the Department of Psychological Sciences at the University of Liverpool are seeking healthy volunteers to take part in a short study investigating individual differences in attention and the way that people attend to pictures of foods. We also interested in finding out if this influences their taste perception.

Eligible volunteers will be asked to take part in an experiment that involves two visits to the university and some reaction time tasks done via the internet. During the visits you will take part in some computer tasks while your eye movements are recorded and complete some questionnaires. You will also be asked to taste up to two of the following foods: cake, chocolate, biscuits, potato crisps and chips. One week after the last university visit we will ask you to complete a short follow-up questionnaire.

If you are **female, aged 18-55, have no food allergies or intolerances and** meet the following criteria you may be eligible to take part:
- Have a BMI above 18.5 kg/m^2 (we will check this for you)
- Are not dieting (not following a structured weight loss programme, e.g. Weight Watchers, Atkins, Slimming World, NHS Weight Loss Group etc).
- Are not currently pregnant
- Are a fluent English speaker
- Have 20/20 or corrected to 20/20 vision (corrected via contact lenses, not glasses)
- Like and regularly consume cake, chocolate, biscuits, potato crisps and chips
- Score within a certain range on a questionnaire that assesses our reaction to food (we will check this for you)
- Are not currently taking part in another appetite-based research study
- Are willing to complete a short computer task on your home/work computer on 5 days out of 7
- Are willing to attend two laboratory testing sessions at the University of Liverpool

Reasonable reimbursement for time and effort will be provided

For more information and to complete the screening questionnaire to assess your eligibility please go to **http://tinyurl.com/AttentionTastePerception** or contact **Bethan Mead** at b.mead@liverpool.ac.uk

UNIVERSITY OF
LIVERPOOL

CONSENT FORM

Title of Research Project: Attention and taste perception
Researcher(s): Drs Emma Boyland, Andrew Jones, Miss Bethan Mead

Please
initial
box

1. I confirm that I have read and have understood the information sheet dated
    October 2015 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 in order to take part in the study, I should meet the following
    criteria:
    - Female
    - Aged 18-55 years old
    - Have a BMI above 18.5 kg/m^2 (we will check this for you)
    - **Not** dieting (not following a structured weight loss program e.g. Weight
    Watchers, Atkins etc)
    - Not currently pregnant
    - Fluent English speaker
    - Have 20/20 or corrected (not glasses) to 20/20 vision
    - Have **no food allergies or intolerances**
    - **Like and regularly consume** cake, chocolate, biscuits, potato crisps and chips
    - Score within a certain range on a questionnaire that assesses our reaction to
    food (we will check this for you)
    - Not currently taking part in another appetite-based research study

3. I understand that if I agree to take part, I will be asked to take part in two lab
    sessions and complete an online follow-up questionnaire. During the lab
    sessions, I will fill out some questionnaires, taste up to two snack foods,
    complete some tasks on a computer and have my height and weight
    measured.

4. I understand I will be asked to complete some reaction time tasks outside of
    the laboratory, via the internet.

5. I understand that I do NOT have to have my height and weight measured to
    participate in this study.

6. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected.

7. I understand that, under the Data Protection Act, I can at any time ask for access to the information I provide and I can also request the destruction of that information if I wish. In addition, I understand that none of my personal details will be recorded, and that my responses are anonymous.

8. I agree to take part in the above study.

_____   _____

_____

Participant Name   Date   Signature

_____   _____

_____

Researcher   Date   Signature

Attention and taste perception study

Online questionnaire 1

Lab Visit 1

Online task
Day 1

Online task
Day 2

Online task
Day 3

5 sessions over 7 days

Online task
Day 4

Online task
Day 5

Lab Visit 2

Online questionnaire 2

amazon
Shopping voucher

Your Participant ID number is:

Website for the online task:

http://research.millisecond.com/semcevoy/AttentionTasteCTrain.web

Your second appointment in the laboratory:

If you have any questions or need
to tell us anything, please contact

Beth - **b.mead@liverpool.ac.uk**