

Individual Differences in Eating Behaviours and Their Relationship with Motivation, Cognition and Weight Control



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THESIS SUMMARY

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A considerable percentage of the UK population are overweight ($\text{BMI} \geq 25 \text{ kg/m}^2$) or obese ($\text{BMI} \geq 30 \text{ kg/m}^2$). However, despite living in the same culture and exposed to a similar “obesogenic” environment, some individuals gain weight while others do not (French et al., 1995). This variability in weight control has been suggested to be associated with individual differences in eating behaviours (French et al., 2012). Certain factors, such as motivation (hedonic hunger and hunger status) as well as cognition (impulsivity and memory) may have an impact on eating behaviours and their relationship with weight control. Thus, the objective of this thesis was to explore individual differences in eating behaviours and investigate their relationship with motivation, cognition and weight control.

The first experiment (Chapter 2) investigated the relationship between eating behaviours, motivation (hedonic hunger) and food consumption during an ad-libitum buffet. This study suggests that restrained eating behaviour was associated with higher overall energy intake, greater energy intake from unhealthy foods and greater energy intake from both high and low energy dense foods. However, no interactions between restraint and disinhibition or hedonic hunger was seen. Following this, the second experiment (Chapter 3) examined whether eating behaviours, such as disinhibition, restraint and hunger, change during a weight loss and weight maintenance period and whether they could predict changes in weight during these periods. Indeed, the results suggest that lower baseline restraint could predict greater weight loss during a low-energy liquid diet and interventions which increase restraint and decrease disinhibition may be beneficial for longer term weight maintenance. The third experiment (Chapter 4) was designed to investigate whether motivation and cognition influences eating behaviours. The results suggest that hedonic hunger, restraint and impulsivity may lead to higher levels of disinhibited eating behaviour. This study was also able to replicate the findings of previous literature suggesting that episodic memory is negatively associated with BMI (Cheke et al., 2016). Finally, following on from the previous study results, the fourth experiment (Chapter 5) included a more diverse sample of participants including dieters. The results provide evidence that individuals on a diet have poorer episodic memory ability than those currently not on a diet. This study also extended previous results suggesting that hedonic hunger (but also episodic memory and hunger) are important factors in disinhibited eating. Hedonic hunger was also shown to be important in levels of hunger.

Acknowledgments

First and foremost, I would like to thank my supervisors Nicky Clayton and Susan Jebb for giving me the opportunity to immerse myself in their laboratories. Having started my PhD in the Medical Research Council Human Nutrition Unit, Susan gave me this opportunity and has supported me ever since. My supervisor Nicky generously invited me to join her lab in my second year and has provided me with endless guidance and support (and hours of talking about dancing) which has been invaluable. Furthermore, Nicky has given me the confidence to explore ideas independently and complete work experience during my PhD.

I would also like to thank the Medical Research Council; without whose funding this PhD would not have been possible. I would like to acknowledge Lucy Cheke at the Department of Psychology, who has given me advice and support to shape this thesis. Thank you for all the help and discussions about my work as well as comments on Chapters 4, 5 and 6. This research would not have been possible without my research volunteers, so my thanks go to them for the time they invested to be a part of it.

I would also like to pay tribute to my research collaborators. From the “DiOGenes” study, thank you to all those involved in this study and especially the project coordinator Wim Saris, the RTD4 study line coordinator Monique Raats, as well as Claus Holst at the Datahub. Thank you also to those who have reviewed my work including Ivonne, Joachim, James, Clare, Stephen, John and Monique. From the buffet study, I would like to highlight the advice and support given by Theresa, Paul, Suzanna, Amy, Hisham and Nenad.

During my PhD, I have also spent time working at GlaxoSmithKline and this would not have been possible if I had not been given the opportunity by the hiring managers at the Human Performance Lab and Clinical Unit Cambridge who enabled me to begin to fulfil my career dreams early and work in industry alongside my PhD.

My PhD experience would have been twice as hard and half as much fun if it were not for my friends both at home and in Cambridge. My heartfelt thanks go to Halliki, Barry, Kien, Chi-Hé, Luke, David, Jane, Naomi, Rebecca, Sarah and others, who have kept me sane during my PhD with so many fond memories that I will forever cherish (especially the hours of dancing together).

Finally, I want to express a huge thank you to my Dad and family. Thank you for believing in me when I didn't and providing love and care, even from afar. Thank you, Dad, for never letting me settle for second best. You've raised me into an ambitious woman who will always “aim for the stars”. I hope I have made you and Mum proud.

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PUBLICATIONS

Chapter 2 includes content from:

Davies KM, Ahern AL, Solis-Trapala I, Westenhoefer J, Stubbs J, Lawton C, Whybrow S, Blundell J, Raats M and Jebb SA, on behalf of the DiOGenes consortium. (2017) *Dietary restraint and disinhibition are associated with weight loss and weight maintenance. Obesity* (in press)

Chapter 3 includes content from:

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Ziauddeen H, Forwood SE, Medic N, Ahern AL, Davies KM, Marteau TM, Jebb SA, Fletcher PC. (2017) *Making Healthier Food Choices: Examining the contribution of goal-directed and habitual decision making to real world food choices* (abstract submitted to British Association for Psychopharmacology and paper in prep)

Publications not included in this thesis:

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O'Neill BV, Davies KM, Morris TE. (2017) *The Singapore Sling: cognitive performance, mood and hormonal profile in Formula 1® race team members during the Singapore Grand Prix*. The Journal of Strength and Conditioning Research (in press)

DECLARATION

This dissertation was carried out under the supervision of Professor Nicola S Clayton at the Department of Psychology and Professor Susan Jebb at the MRC Human Nutrition Unit at the University of Cambridge. All parts of this dissertation are the result of my own work except for those aspects detailed below.

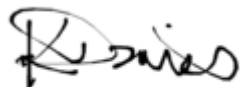
In Chapter 2, this study was designed as a collaboration between the MRC Human Nutrition Research unit, the Department of Public Health and Primary Care and the Department of Psychiatry at the University of Cambridge. Nenad Medic and I primarily collected the data and data was interpreted in discussion with Amy Ahern.

In Chapter 3, the data was collected as part of the “Diet, Obesity and Genes” project led by Professor Wim Saris, Maastricht University and the RTD4 study line coordinators Professor Monique Raats and Dr Claus Holst. I received data analysis advice from Ivonne Solis-Trapala and the data was interpreted in discussion with Amy Ahern.

Chapters 4 and 5 were designed and the data was subsequently interpreted with discussions and advice from Lucy Cheke.

The study design from the experiment in Chapter 3 were submitted as part of a Doctoral qualification by Nenad Medic in 2016. No other part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution.

This length of this thesis does not exceed the word limit.

A handwritten signature in black ink, appearing to read 'N. Medic', is located at the bottom left of the page.

CHAPTER 1

GENERAL INTRODUCTION

1.1 Obesity

Obesity is defined as a body mass index (BMI) of ≥ 30 kg/m² and is a major public health problem not only in the UK, but in the majority of the Western world. In 1997, the World Health Organization consultation recognized obesity as an 'epidemic' (Consultation, 2000). By 2014, it was recorded that more than 1.9 billion adults aged 18 or over were overweight (having a BMI of ≥ 25 kg/m²) and 600 million of these were individuals with obesity. Furthermore, between 1980 and 2014 the worldwide prevalence of obesity more than doubled (WHO, 2015). Here in the UK in 2015, 62.9% of adults were overweight or obese (67.8% of men and 58.1% of women) and 26.9% of adults were obese (Moody, 2016). Obesity is strongly associated with serious health problems such as diabetes, heart disease, and some cancers (Flegal et al., 2010). Consequently obesity has an impact not only on an individual's personal health, but also puts a huge burden on the demand for health care (Swinburn et al., 2011). Obesity develops when energy intake from consuming food and drink outweighs that of energy expenditure through metabolism and physical activity.

1.2 Weight control

Controlling body weight involves a fine balance between energy intake, energy expenditure and energy storage (Hill et al., 2012). When energy intake and energy

expenditure are equal, body energy and body weight is stable. However, when energy intake is greater than energy expenditure, there is a positive energy balance leading to increased body mass of which 60-80% is usually body fat (Hill and Commerford, 1996). On the other hand, when energy expenditure is greater than energy intake, there is a negative energy balance leading to a decrease in body mass (again with 60 to 80% from body fat). The current environment has been labelled as 'obesogenic or obesity-causing' (Pincock, 2011), because high energy dense food and drinks are readily available and sedentary leisure activities and travelling by car are now the norm. Therefore, individuals find it difficult to maintain a healthy body weight. It has been suggested that a moderate amount of weight loss to achieve a healthy body weight can decrease the levels of some of the co-morbidities associated with obesity, including high blood pressure, without the individual even reaching their ideal weight (Graffagnino et al., 2006). As such, a number of weight loss interventions are available for individuals to try and maintain the energy balance in order to control their weight.

Weight loss and weight maintenance

Although the benefits of maintaining a healthy weight and reducing the risk of obesity may be obvious, treating and managing obesity can be complex and there are several ways in which people choose to lose weight, for example, commercial weight loss programmes, low energy diets, healthy eating or even bariatric surgery.

In the UK, the National Health Service (NHS) referral schemes currently recommend the use of commercial weight loss programmes such as Slimming World and Weight Watchers. A third of those who were referred to Weight Watchers achieved 5% weight loss over a 12-session course (Ahern et al., 2011). Furthermore, when 317 individuals

were assigned to 12 months free Weight Watchers membership they found that mean weight change at 12 months was -5.06kg (Jebb et al., 2011). Similarly, when 34,271 patients were referred to another weight loss programme, called Slimming World, for 12 weekly sessions, those who attended more than 10 sessions also achieved 5% weight loss (Stubbs et al., 2011). Research has also shown that individuals who complete commercial weight loss programmes also benefit from weight maintenance, as of the 699 participants who participated 79.8% after one year, 71% after two years and 50% after five years maintained 5% of their weight loss after completing a Weight Watchers programme (Lowe et al., 2007).

Another predominantly self-initiated diet is one which involves reducing energy intake, such as a Low- or Very Low-Calorie Diets (LCD/VLCD). A low-calorie diet provide 800-1500kcal/day from food or meal replacements with an average weight loss of 11.4kg (Anderson et al., 2004). For example, a multicentre, weight loss study using an 8-week low-calorie diet found that the 773 adults who completed the diet successfully lost approximately 11.1kg (Papadaki et al., 2013). Very low-calorie diets, however, provide only 400-800kcal/day (Anderson et al., 1992). The traditional five shakes/day VLCD diets (~500kcal/day), initiated in the 1980s, have shown that individuals lose approximately 2% of their initial body weight per week for the first 8 weeks and those who have excellent adherence and who have an initial BMI of $>35\text{kg/m}^2$ can lose about 35kg in this time (Anderson et al., 1992). Very low-calorie diets also achieve an average weight loss of 24.1kg after 6 months and weight maintenance of 6.6kg after a 54 month follow-up (Anderson et al., 2004). However, despite this rapid weight loss, low calorie diets and very low-calorie diets are no more effective in the long term (after 1 year) than less restrictive, low energy diets (Clark et al., 1994). Evidence also suggest that Total Diet

Replacement programmes provide similar weight loss to VLCDs, but provide 800-1000kcal/day and are suggested to have better adherence (Noakes et al., 2004).

Low and very low-calorie diets can often be hard to adhere to (Christensen et al., 2011, Tsai and Wadden, 2006) and therefore the National Institute for Health and Care Excellence (NICE) provides recommendations to the general public on healthy eating strategies to help people achieve and maintain a healthy weight. For example, NICE suggests that individuals aiming for a healthy weight should eat five portions of fruit and vegetables per day, eat breakfast, minimise alcohol intake, and eat plenty of fibre-rich foods, such as oats and grains (National Institute for Health and Clinical Excellence, 2006). In addition to general advice on a healthy lifestyle, there are several diet-based weight loss programmes, such as low-carbohydrate diets or low-fat diets. Low carbohydrate diets contain less than 200g of carbohydrates per day, or less than 30% of an individual's total daily energy requirement (Adam-Perrot et al., 2006). When an 8-week low fat diet (20% fat, 60% carbohydrate) versus an 8-week low carbohydrate diet (60% fat, 20% carbohydrate) was tested in a randomized controlled trial, individuals lost 7.3kg of weight on the low carbohydrate diet compared with 6.5kg on the low fat diet (Bradley et al., 2009). Nevertheless, after a 1-year follow-up period, there was no difference in the amount of weight maintained between the two diets (Frigolet et al., 2011)

More invasive options for managing obesity include drug treatment and bariatric surgery. Since the suspension of Sibutramine (Reductil) from the market in 2010, the only drug currently prescribed by the NHS for weight loss is Orlistat. It is given to adults with a BMI $\geq 30\text{kg/m}^2$ or those with a BMI of $\geq 28\text{kg/m}^2$ with other associated risk factors

and is recommended to be taken under the direction of health professionals who can provide support and counselling on additional diet, physical activity and behaviour (NICE, 2006). However, a lower dose of Orlistat can be obtained over-the-counter from pharmacies. In comparison to placebo, Orlistat reduced body weight by 2.9kg after approximately a 1-year follow-up in 16 studies (Rucker et al., 2007). Bariatric surgery is also recommended as a treatment for adults who have a BMI $\geq 40\text{kg/m}^2$, or those who have a BMI of 35-40kg/m² with other significant diseases such as high blood pressure and who have tried all other non-surgical treatments with no success. Whereas, for individuals with a BMI $\geq 50\text{kg/m}^2$, bariatric surgery is considered a first-line option (Health, 1998). Bariatric surgery is associated with weight loss of 14.4-24 kg (Maggard-Gibbons et al., 2013), however following surgery individuals often regain weight due to lack of exercise and returning to their preoperative eating habits (Sjöström et al., 1999). Taken together, these findings suggest that those people who are overweight or obese have a variety of options to lose weight. These interventions include changes in diet, eating behaviour or more drastically surgery and drugs. However, despite this range of options, many individuals remain overweight. The development of obesity results from a multitude of factors that cause people to overeat and gain weight. This thesis will explore weight control in terms of both energy intake and weight changes during weight loss and weight maintenance.

1.3 Eating behaviours

The international obesity problem and the stress on the importance of maintaining a healthy weight have led to an increased interest in the factors that influence weight control (Kopelman, 2007), particularly energy intake, in both the media and academic

research. However, in the current obesogenic environment not everyone becomes obese and while some individuals are able to lose weight during a weight loss programme, others struggle to do so (Brownell, 2010). These differences in weight control have been suggested to be associated with individual differences in eating behaviours, such as disinhibition, restraint and hunger.

Disinhibition

Disinhibition is the tendency to overeat or eat opportunistically in an obesogenic environment. For example, not being able to resist stimulation to eat and overeating in the presence of palatable food would be characteristic of a disinhibited individual. Disinhibition has become more prominent since the development and widespread use of the Three Factor Eating Questionnaire (TFEQ) (Stunkard and Messick, 1985). More recently, a factor analysis of the TFEQ was carried out in which three subscales of disinhibition were identified: “habitual” disinhibition (the susceptibility to overeat in response to daily life circumstances), “emotional” disinhibition (the tendency to overeat in response to emotional states such as anxiety or depression), and “situational” disinhibition (the susceptibility to overeat in response to specific environmental cues such as social occasions) (Bond et al., 2001). However, only a few authors to date have used these sub-scales.

One component of disinhibition that has been studied a huge amount in the literature is external eating, which is defined as the “inability to resist food when in its presence or if there are sensory cues to eat” (Braet and VanStrien, 1997). In the current environment, external eating has been described as the disinhibition of eating by shifting one’s attention to the readily available food (Dovey, 2010). External eaters,

therefore, will consume food when it is available despite having little or no physiological hunger signals. This is often referred to as the 'bakery effect' (Dovey, 2010); a person passes a bakery, smells food and feels hungry. However, it is important to mention that all five senses can lead to the external cues to eat. External eating is measured using the Dutch Eating Behaviour Questionnaire (DEBQ), which includes a subscale for external eating (van Strien et al., 1986).

A body of evidence has shown that disinhibition and external eating are positively associated with BMI and body weight. Individuals who were more disinhibited (higher TFEQ-disinhibition score or higher DEBQ-external eating score) had a greater BMI or body weight (Provencher et al., 2003, Provencher et al., 2007, Boschi et al., 2001, Dykes et al., 2004, Bellisle et al., 2004, Williamson et al., 1995, Fayet et al., 2012, Aurelie et al., 2012, Zyriax et al., 2012, Epstein et al., 2012, Hays et al., 2002, Lawson et al., 1995, Carmody et al., 1995, Gallant et al., 2010, Chaput et al., 2009, Hainer et al., 2006, Harden et al., 2009, Lindroos et al., 1997, Thomas et al., 2013, Schubert and Randler, 2008). Some studies have also found that TFEQ disinhibition is higher in women than in men (Aurelie et al., 2012, Provencher et al., 2003).

Restraint

Unlike disinhibition, restraint is the conscious restriction of food intake to prevent weight gain or to promote weight loss. The construct is made up of two distinct behavioural subscales: rigid control, characterized by an 'all or nothing' approach, and flexible control, a 'more or less' approach to weight and eating (Westenhoefer et al., 1994). The development of the 'Restraint Theory' in the 1970s, stemmed from a high-calorie preload study demonstrating that attempting to reduce energy intake as a means

of achieving weight control actually increased intake of palatable foods (Herman and Polivy, 1975). Since then, key features of dietary restraint have been investigated by a huge body of research.

Restrained eating was originally measured by the Restraint Scale (RS). However, researchers have questioned its validity as a measure of dietary restraint due to limitations of criterion confounding (Wardle, 1988, Stunkard and Messick, 1985). Items on the restraint scale seem to measure directly overeating and disinhibition (Stunkard and Messick, 1985). In order to overcome this confounding, the Three Factor Eating Questionnaire (TFEQ) (Stunkard and Messick, 1985) and Dutch Eating Behaviour Questionnaire (DEBQ) (van Strien et al., 1986) were developed, which both include a restraint sub-scale. A construct validity study showed that high scores on the TFEQ-R and DEBQ-R were associated with energy restriction (Laessle et al., 1989b).

Research exploring the relationship between restraint and body weight has revealed inconsistent results. While some studies have shown restraint scores are positively associated with BMI (Hill et al., 1991, Tuschl et al., 1990b, Fayet et al., 2012, Aurelie et al., 2012, Gallant et al., 2010, Thomas et al., 2013), some have shown a negative association (Boschi et al., 2001, Williamson et al., 1995, Hainer et al., 2006, Foster et al., 1998) and yet others have shown no associations (Drapeau et al., 2003, Provencher et al., 2003, Lawson et al., 1995, Schubert and Randler, 2008, Lindroos et al., 1997, Harden et al., 2009, Bellisle et al., 2004, Dykes et al., 2004). In individuals with obesity, greater restraint is usually associated with lower weight (Bellisle et al., 2004, Provencher et al., 2003, Foster et al., 1998), whereas in normal weight individuals with greater restraint usually have a higher weight (de Lauzon-Guillain et al., 2006). In addition, it seems that

women have higher restraint than men, regardless of BMI (Provencher et al., 2003, Hainer et al., 2006, Aurelie et al., 2012, Zyriax et al., 2012, Carmody et al., 1995).

Restraint may not act alone, but may interact with disinhibition, when measured by the TFEQ-D. Cross-sectional studies have shown evidence that those with a lower BMI had high restraint and low disinhibition, while those with a higher BMI had high disinhibition and low restraint (Dykes et al., 2004, Hays et al., 2002, Williamson et al., 1995). Furthermore, it has been suggested that when someone has both high disinhibition is high and a high level of restraint, the relationship between weight and disinhibition is weakened (Hays et al., 2002, Williamson et al., 1995, Hays and Roberts, 2008, Dykes et al., 2004). Evidence from these studies suggests that in normal weight individuals, greater restraint may act as a risk factor for the tendency to overeat, whereas in overweight individuals, greater restraint may protect against the adverse appetitive effects of weight gain.

Hunger

The hunger construct (predisposition of hunger) is also measured by the Three Factor Eating Questionnaire (TFEQ hunger subscale) and is defined as the susceptibility for internal and external hunger (Stunkard and Messick, 1985). As such, a factor analysis of the TFEQ revealed two subscales of hunger: an internal locus for hunger (hunger that is interpreted and regulated internally e.g. 'I am usually so hungry that I eat more than three times a day') and an external locus for hunger (hunger triggered by external cues e.g. 'being with someone who is eating often makes me hungry enough to eat also') (Bond et al., 2001). However, relatively few authors to date have used these subscales. It has been reported that generally, like disinhibition, obese individuals have higher

hunger scores than non-obese individuals, i.e. there is a positive association between TFEQ hunger score and BMI or body weight (Karlsson et al., 1994, Lindroos et al., 1997, Provencher et al., 2003, Boschi et al., 2001). There seems to be an unclear difference in hunger between men and women, for example, while one study showed that men had higher hunger scores than women (Provencher et al., 2003), other studies have showed no difference in hunger scores between men and women (Aurelie et al., 2012, Gallant et al., 2010).

Relationship between eating behaviours and weight control

While disinhibition, restraint and hunger have been shown to be associated with BMI and body weight, studies have also explored the relationship between these eating behaviours and weight control (i.e. energy intake and weight change). The majority of studies have shown that disinhibition is positively associated with energy intake during laboratory ad-libitum meal tests (Westenhoefer et al., 1994, Haynes et al., 2003, Finlayson et al., 2012, Chambers and Yeomans, 2011, Lindroos et al., 1997) and food frequency questionnaires or diaries (Contento et al., 2005, Lahteenmaki and Tuorila, 1995, Provencher et al., 2003). Those with higher disinhibited eating consumed more food or reported higher energy intake. However, other studies have found that disinhibition was not related to food consumption, particularly of savoury crackers eaten (Ouwens et al., 2003) or ice-cream eaten after a milkshake preload (Van Strien et al., 2000). Furthermore, women with greater TFEQ-disinhibition scores have been shown to have a higher preference for high fat foods on a food preference questionnaire (Bryant, 2006). In addition, studies have shown that decreased disinhibition over time is associated with decreased energy intake (Drapeau et al., 2003) and decreased

consumption of high-fat, high-sugar foods (Borg et al., 2004). Hunger, as measured by the TFEQ, has also been shown to be associated with greater energy intake (Lindroos et al., 1997, Keim et al., 1996).

Unlike disinhibition and hunger, restraint scores do not show reliable associations with energy intake. Some studies have shown that greater restraint is associated with healthier food choices (Contento et al., 2005, Lahteenmaki and Tuorila, 1995) and decreased energy intake (Lindroos et al., 1997, Hays et al., 2002, Provencher et al., 2003, Laessle et al., 1989a, De Castro, 1995, French et al., 2014). Other studies, however, have found either no association (Van Strien et al., 2000, Westenhoefer et al., 1994, Chambers and Yeomans, 2011, Finlayson et al., 2012, Stice et al., 2004, Stice et al., 2007) or a positive association between energy intake and levels of restraint (Ouwens et al., 2003). A small number of studies have shown that disinhibition and restraint have an interactive effect on energy intake. Individuals with both high disinhibition and low restraint had higher energy intake, whereas those with low disinhibition and high restraint had lower total energy intake (Westenhoefer et al., 1994, Westenhoefer, 1991).

A great amount of research has also been carried out to investigate the relationship between disinhibition, restraint and hunger, and weight change in both prospective studies and interventional weight loss studies. Prospective studies have found that an increase in disinhibition over time was related to weight gain (McGuire et al., 1999) and higher disinhibition scores at baseline predicted weight gain (Savage et al., 2009, Wing et al., 2008, Chaput et al., 2009). Most weight loss intervention studies have shown that a decrease in disinhibition is associated with weight loss during the intervention (Bjorvell

et al., 1994, Clark et al., 1994, Richman et al., 1996, Kiernan et al., 2001, Chaput et al., 2005, Chaput et al., 2010, Frestedt et al., 2012, Bryant et al., 2012, Dalen et al., 2010, Teixeira et al., 2010, Karhunen et al., 2012, Riesco et al., 2009, Grave et al., 2009) and weight maintenance after an intervention (Levine et al., 2007, Cuntz et al., 2001, Fogelholm et al., 1999). However, this was not true for all studies, some studies found that whilst disinhibition decreased during a follow up period this was not related to weight loss (Wadden et al., 2004, Vogels et al., 2005). Furthermore, it is unclear whether baseline disinhibition can predict the amount of weight lost during weight loss interventions and post intervention weight maintenance. Several studies have shown that baseline disinhibition is able to predict weight loss during the intervention (LaPorte and Stunkard, 1990, Pekkarinen et al., 1996, Karlsson et al., 1994). However, Foster et al. found no relationship between baseline disinhibition and weight loss despite seeing a decrease in disinhibition associated with weight loss during the treatment period (Foster et al., 1998).

Longitudinal studies have also examined associations between dietary restraint and weight change in free-living individuals. Studies have shown that within-person increases in restraint over time were associated with weight loss (Savage et al., 2009, Foster et al., 1996, Tucker and Bates, 2009, Dalle Grave et al., 2009) and weight maintenance after weight loss (Wing et al., 2008, McGuire et al., 1999, Vogels et al., 2005, Vogels and Westerterp-Plantenga, 2007). Furthermore, in a 6-year prospective study of 283 individuals from the Quebec Family Study, restraint behaviour was negatively correlated with changes in body weight. In men, a high restraint score seemed to promote weight loss. However, in women, high restraint seemed to promote weight gain (Drapeau et al., 2003). Moreover, in the same sample of people and same

time frame, those with high restraint, but also high disinhibition, were more likely to gain weight (Chaput et al., 2009).

Restrained eating has developed a lot of interest as a successful strategy for weight loss. Several studies have shown that greater restraint was able to predict greater weight loss during weight loss interventions (Dalle Grave et al., 2009, LaPorte and Stunkard, 1990, Pekkarinen et al., 1996). Furthermore, in studies using weight loss programmes—whether it was a low-calorie diet, meal replacement, behavioural intervention or multidisciplinary approach—restraint increased during the course of the intervention (Westerterp-Plantenga et al., 1998, Wadden et al., 2004, Clark et al., 1994, Richman et al., 1996, Kiernan et al., 2001, Chaput et al., 2005, Frestedt et al., 2012, Dalen et al., 2010, Karhunen et al., 2012, Levine et al., 2007). Moreover, several weight-reduction treatment programs showed that greater increases in restraint are associated with greater weight loss (Foster et al., 1998, Borg et al., 2004, Riesco et al., 2009, Teixeira et al., 2010, Bryant, 2006, Bjorvell et al., 1994) and weight maintenance (Karhunen et al., 2012, Levine et al., 2007, Vogels et al., 2005). More recent studies have explored the effects of promoting dietary restraint as part of a weight control programme and found that increasing dietary restraint was associated with greater weight loss (Rapoport et al., 2000, Lowe et al., 2001). Furthermore, restraint has also been shown to increase after weight loss surgery (Kalarchian et al., 1999, Lang et al., 2002, Guisado Macias JA, 2003, Schindler et al., 2004) and with weight loss drugs (Lejeune et al., 2003, Hainer et al., 2005). Dietary restraint, therefore, appears to assist in weight loss and weight maintenance.

Research has also been conducted to investigate the relationship between hunger and weight in both prospective studies and intervention studies. Greater increases in hunger has been shown to be associated with weight gain (McGuire et al., 2001) and hunger scores predicted weight maintenance following weight loss (Pasman et al., 1999). A decrease in hunger has also been shown to be associated with weight loss during weight loss intervention studies have shown that a decrease in hunger is associated with weight loss (Pekkarinen et al., 1996, Foster et al., 1998, Batra et al., 2013). However, one study found that hunger decreased during a 20-week intervention period, but this was not related to weight loss (Wadden et al., 2004). Unlike the relationship between changes in hunger and weight change, there seems to be an unclear picture as to whether baseline TFEQ hunger can predict the amount of weight lost during weight loss interventions and post intervention weight maintenance. Several studies have shown that baseline hunger is able to predict weight loss during the intervention and maintaining a lower weight after the intervention (McGuire et al., 2001, Batra et al., 2013, Bryant et al., 2012). However, Foster and colleagues found no relationship between baseline hunger and weight loss, despite seeing a decrease in hunger with weight loss during the treatment period (Foster et al., 1998).

Together, these results suggest that disinhibition, restraint and hunger eating behaviours are all important in energy intake, weight change and overall weight control. However, underlying motivational factors, such as homeostatic and hedonic hunger may influence these eating behaviours.

1.4 Motivational factors

An individual's eating behaviour profile is a key factor in understanding overeating and obesity. However, these behaviours are descriptive indices of how one acts around food. A body of evidence suggests that both homeostatic and psychological factors contribute to the regulation of consumption. The decision to eat is made in accordance with hunger and satiety controlled not only by physiological homeostatic signals, but also by a psychological assessment of what has recently been eaten, and consumption opportunities which may occur in the near future (Wansink and van Ittersum, 2007, Robinson et al., 2013b).

Homeostatic hunger

Homeostatic hunger is the hunger needed to maintain energy balance. These hunger signals are relayed by circulating hormones, such as leptin and ghrelin, which relay information about peripheral energy levels to the brain. Leptin is made by white adipose tissue and when leptin levels increase, it suppresses food intake and stimulates metabolic processes to disperse energy stores (Zigman and Elmquist, 2003). On the other hand, ghrelin is a stomach-derived peptide which stimulates energy storage and food intake in response to a negative energy balance (Zigman and Elmquist, 2003). Although homeostatic hunger works to maintain an energy balance, not everyone eats when they are 'hungry'. As such, individuals eat, even when they do not need to and this type of "hunger" has more to do with seeking pleasure than the need for calories, known as hedonic hunger (Lowe and Butryn, 2007). Notably, the boundary between homeostatic and hedonic hunger is unclear. An individual who goes for 2-3 hours without eating is not in energy deprivation, but if the same individual has no food for 24 hours then they are. The point at which the homeostatic hunger happens due to lack of

energy is not straightforward and probably varies by individual and the level of energy expenditure (Lowe et al, 2005).

Hedonic hunger

Hedonic hunger is defined as the tendency to experience thoughts, feelings and urges about food in the absence of any short- or long-term energy deficit (Lowe and Butryn, 2007). Hedonic hunger is measured by the Power of Food Scale (PFS), which was designed to detect individual differences in appetitive responsiveness (Lowe et al., 2009). This is a 15 item self-report scale and higher scores indicate greater hedonic hunger, as described in Chapter 2. The PFS does not include any items describing actual food consumption (or over-consumption) as the aim is to measure appetite for, rather than consumption of palatable foods. This approach is advantageous because it avoids confounding between PFS items and the tendency to overeat, as the PFS is used to predict consumption. The PFS is only suitable for populations where food is readily available, because food-related thoughts may then be explained by homeostatic hunger (Lowe and Butryn, 2007).

There seems to be a complex relationship between hedonic hunger and BMI, because although some studies have shown hedonic hunger to be associated with BMI, not all studies show this same association. Two studies found that obese or severely obese individuals had greater hedonic hunger than non-obese individuals (Schultes et al., 2010, Ullrich et al., 2013a). Furthermore, Cappelleri et al. found a weak correlation between BMI and hedonic hunger in 1275, overweight, obese and normal weight adults in a web-based survey. However, in the same study, in 1741 obese adults in a clinical trial for a weight management drug, there was no association of BMI with hedonic hunger

(Cappelleri et al., 2009). Moreover, one study categorised individuals into either an 'obesity resistant' or 'obesity prone' group, matched for age, sex, and ethnicity/race and showed that baseline hedonic hunger was higher in the 'obesity prone' group (Thomas et al., 2013). Notably, there seems to be no gender differences in hedonic hunger (Schultes et al., 2010). These findings suggest that hedonic hunger reflects an individual's tendency of being preoccupied with food without any short-term energy deficit, which has a complex relationship with BMI. It is, therefore, important to understand the relationship between hedonic hunger and weight control as well as eating behaviours.

Relationship between motivation and weight control

Experimentally, the relationship between hedonic hunger and food intake has been tested by giving female undergraduates a transparent box of chocolate kisses for two days while abstaining from all chocolate consumption. Despite participants being told not to eat the chocolates, about 10% of them did. The PFS was positively related to those who ate the chocolates (Forman et al., 2007).

There are only a few weight loss intervention studies that have investigated the relationship between hedonic hunger and weight change. The only behavioural weight loss intervention study, by O'Neil et al., showed that hedonic hunger decreased with two variants of a commercial weight loss intervention (Weight Watchers) and this decrease in hedonic hunger was associated with weight loss. However, there was no difference between the weight loss interventions investigated and they had no control group. They also showed that baseline hedonic hunger did not predict weight loss (O'Neil et al., 2012). Some studies have investigated hedonic after gastric banding

surgery. All studies found that hedonic hunger decreased after surgery (Schultes et al., 2010, Ullrich et al., 2013b). Taken together, the evidence suggests that both homeostatic and hedonic hunger may be important in energy intake and weight control.

1.5 Cognitive Factors

Like motivation, cognitive factors such as impulsivity and memory have started to gain more interest by researchers wishing to understand their relationship with eating behaviours and weight control. It has been suggested that internal and external sensory information is likely to be processed or 'filtered' by brain regions responsible for cognition (Booth, 2008). A body of evidence showing the importance of cognitive factors such as impulsivity and episodic memory in eating behaviour has emerged and is discussed below.

Impulsivity

Researchers have found it difficult to formulate a single definition of impulsivity that captures every aspect encompassed by this concept, which includes rapid decision-making, inattention, lack of perseverance, acting without thinking, lack of planning, sensation seeking, and risk-taking (Moeller et al., 2001). It has been described as "experiencing a sudden and unplanned urge to behave in a hedonically pleasing manner that is immediately gratifying and then acting on the impulse without careful deliberation on subsequent negative consequences" (Sengupta and Zhou, 2007). In a food-related context, a typical impulsive behaviour would be to choose and consume an unhealthy cake over a healthy salad due to strong impulses of favouring the cake over the salad (Shiv and Fedorikhin, 1999). Research into the causes of obesity have suggested that impulsivity is linked to obesity and overeating (Guerrieri et al., 2008) and

that high impulsivity in individuals can play a role in the progress and maintenance of obesity (Davis, 2009).

Given the multiple constructs of impulsivity, there are different tasks or questionnaires to measure each of these. The most widely used self-report questionnaire is the Barratt Impulsiveness scale (BIS-11) (Patton et al., 1995, Monahan and Steadman, 1994). The BIS-11 is a 30-item questionnaire that assesses three second-order factors of impulsivity, which include, motor impulsiveness, non-planning impulsiveness and attentional impulsiveness (Patton et al., 1995). However, there are other questionnaires available, for example, the Impulsive Behaviour scale (UPPS) (Whiteside and Lynam, 2001), a 45-item Likert-type scale with four subscales: lack of premeditation, urgency, sensation-seeking and lack of perseverance. There are also a number of computer tasks to measure impulsivity, two of these tasks include the go/no-go task and stop-signal reaction time (SSRT) task (Band and van Boxtel, 1999). During a go/no-task, the subject is trained to make a response (e.g., a key-press) when presented with a 'go' signal over multiple trials. On some trials, a 'stop' signal is presented just prior to, or simultaneously with the 'go' signal and the subject must inhibit the impending response. The SSRT is similar, except that the 'stop' signal is presented after the 'go' signal. This small modification increases the difficulty of inhibiting the 'go' response, because the participant has typically already initiated the 'go' response by the time the 'stop' signal is presented.

Studies among adults have reported mixed or null findings regarding associations between weight and measures of impulsivity. For example, in behavioural tasks (e.g. go/no-go, stop signal or delay discounting tasks), overweight and obese individuals tend to be more impulsive than lean individuals (Nederkoorn et al., 2006, Weller et al., 2008,

Schiff et al., 2016, Mobbs et al., 2011). Furthermore, studies have also shown that greater impulsivity scores on questionnaires, such as the BIS-11, are associated with a greater BMI (Yeomans et al., 2008, Meule and Blechert, 2016, Mobbs et al., 2010, Rydén et al., 2003). However, numerous studies have not found an association between body mass and behavioural or self-reported measures of impulsivity (Hendrick et al., 2012, Koritzky, 2012, Loeber et al., 2012, Verdejo-García et al., 2010). Thus, the relationship between impulsivity and BMI seems to be dependent on which measure of impulsivity has been used.

Episodic memory

Episodic memory refers to the ability to consciously recall past episodes or events which we have experienced (Tulving, 1972, Tulving, 1983) and is accompanied by the subjective awareness of being the author of the memory, so-called autonoesis (Wheeler, 2000) , together with an awareness of the subjective sense of time, so-called chronesthesia (Tulving, 2002). Crucially it involves the projection of self in time (Tulving, 1985, Suddendorf and Corballis, 1997, Schacter and Addis, 2007, Buckner and Carroll, 2007). Given that episodic memory requires the personal experience of remembering, researchers have slightly different working definitions of episodic memory, which has led to inconsistencies in how episodic memory performance is measured. The different measures include: free recall tasks (Tulving, 1985), source memory tasks (e.g. (Johnson, 1997, Davachi et al., 2003, Lundstrom et al., 2005)), unexpected questions (Zentall et al., 2001, Zentall et al., 2008) and the ability to remember the What-Where-When of past events (Cheke et al., 2017, Cheke et al., 2016, Clayton and Dickinson, 1998). However, it has been found that all of these episodic memory tests are not necessarily measuring

the same thing (Cheke and Clayton, 2013, Cheke and Clayton, 2015). For the experiments in this thesis, episodic memory was measured using a what-where-when (WWW) paradigm. This paradigm was derived from Clayton and Dickinson's comparative work on food caching by Californian scrub-jays. They argued that in the absence of agreed behavioural markers of the phenomenological features of autonoesis and chronesthesia, one cannot evaluate whether or not animals episodically recall the past for absence of evidence is not evidence of absence. What one can do, they argued, is to develop tests that investigate the behavioural components of episodic memory, which they called episodic-like memory (Clayton et al., 2003a, Griffiths et al., 1999). Specifically they suggested that in terms of content, the memory for each past event would contain information about what happened, where it happened and when it happened (Clayton and Dickinson, 1998), and that in terms of structure the information would be integrated or bound together (Griffiths et al., 1999), and finally that this memory would be part of the declarative system and therefore be highly flexible and thus it is possible to update the memory at a later time, subject to new information (Clayton et al., 2003a).

Whilst this WWW test has been used extensively in animal cognition research to assess "episodic-like" memory (e.g., (Clayton and Dickinson, 1998, Clayton et al., 2001, Clayton et al., 2003b, de Kort et al., 2005, Babb and Crystal, 2006), recent research has adapted this paradigm for testing both young children (e.g. (Russell et al., 2011, Clayton, 2015)) and adults (Cheke and Clayton, 2013, Cheke and Clayton, 2015). Of special relevance here is that it has been developed into a computer task for adult humans, known as the Treasure Hunt Task (THT) (Cheke et al., 2017, Cheke et al., 2016, Cheke, 2016). This task (described further in Chapter 4) requires the participant to remember object, location

and temporal order information and the ability to integrate each of these features (Cheke et al., 2016).

Research here in the Department of Psychology in Cambridge has shown that higher BMI was associated with poorer performance on the THT in all individual subtasks as well as the what-where-when integration (Cheke et al., 2016). Although, a subsequent study found no significant difference in any of the THT subtasks between lean and obese individuals, when subjects were grouped by their level of insulin resistance, those with higher insulin resistance had a poorer performance on the what-where-when integration subtask. In the same study, the subtasks which involved integration of object, location and temporal information (encoding and what-where-when retrieval) elicited activity in the left hippocampus and left angular gyrus (Cheke et al., 2017). These regions are associated with combining episodic features into a memory representation (Burgess et al., 2002, Shimamura, 2011, Yazar et al., 2012, Yazar et al., 2014). This evidence suggests that both impulsivity and episodic memory may be important factors in energy intake and weight control.

Relationship between cognition and weight control

Both impulsivity and episodic memory have been shown to influence energy intake. Studies have shown that those who had higher impulsivity (higher score on an SSRT task) had heightened food intake during bogus taste tests (Guerrieri et al., 2007, Nederkoorn et al., 2009) and ad-libitum eating tasks (Appelhans et al., 2011), but not with candy consumption (125g of M&M sweets) (Hofmann et al., 2009). However, in one study an increase in impulsivity was only related to an increase in food intake when feeling hungry (Nederkoorn et al., 2009). One study showed that the BIS-11 was associated with

energy intake during a bogus taste test (Guerrieri et al., 2007). More recently, Guerrieri et al. carried out work to prime individuals with impulsivity in the form of a memory task. They found that those in the impulsive condition consumed more calories during a bogus taste test than those in the control condition (Guerrieri et al., 2009). In addition to influencing energy intake, impulsivity, measured by the SSRT, has also been shown to be associated with increased food purchasing (Nederkoorn et al., 2009).

In addition to impulsivity influencing energy intake, it has also been shown that recalling a preceding meal can affect the amount of food eaten during a subsequent meal (Higgs, 2002). The relationship between episodic memory and food intake was originally derived from a clinical report which showed that a 54 year old man who had a bilateral resection in the medial temporal lobe region rarely commented about his hunger or thirst (Hebben et al., 1985). Furthermore, Rozin and colleagues showed that patients with amnesia who were unable to recall events from 2 minutes earlier continued to eat identical lunchtime meals and appeared to be unaware of the previous meal. Whereas, matched control subjects tended to eat the majority of first meal and rejected the second identical meal when offered (Rozin et al., 1998a). More recent research has investigated how episodic memories of recent meals affect subsequent food intake. Evidence suggests that cueing participants to recall a previous recently eaten meal reduces the amount of food eaten during taste tests (Higgs, 2002, Higgs, 2008). Furthermore, studies have also shown that diverting a participant's attention, by watching television whilst consuming a meal to interrupt the encoding or formation of memory for that meal, led to increased consumption in a later eating session compared to when participants were not distracted (Higgs and Woodward, 2009, Oldham-Cooper et al., 2011). In addition, enhancing a memory for a recent lunchtime meal, by focusing

on the sensory characteristics of the food as they consumed it, has been shown to have the opposite effect and in fact reduced intake at a later afternoon intake session (Higgs and Donohoe, 2011). Collectively, these studies suggest that both impulsivity and episodic memory are important in energy intake and therefore weight control.

As well as having an influence on energy intake, it seems impulsivity is also a predictor of weight gain (Sutin et al., 2011). The trajectory of BMI across adulthood was modelled in order to test whether personality predicted its rate of change. Impulsivity-related traits predicted a greater increase in BMI across the adult life-span and those who scored in the top 10% of impulsivity weighed, on average, 11kg more than those in the bottom 10% (Sutin et al., 2011). Furthermore, a prospective study showed that those with high impulsivity gained the most weight over time (Nederkoorn et al., 2010).

While several studies have shown that impulsivity is associated with weight control, there is only one study to date which has looked at the relationship between diet-induced weight loss and episodic memory. Using a face-name paradigm as a measure of episodic memory, Boraxbeek and colleagues assigned 20 middle aged women to 6 months of a Palaeolithic diet or a standard healthy eating diet and measured episodic memory before and after the diet. They found that memory performance was significantly improved in both diets with no significant differences between the two groups, suggesting that dieting for weight loss may improve episodic memory (Boraxbeek et al., 2015).

Evidently, eating behaviours, cognitive and motivational factors have a complex relationship with weight control. As such, these factors may interact to influence eating behaviours. The following section will explore how these cognitive and motivational

factors may influence the relationship between eating behaviours and weight control by discussing the relationships between eating behaviours, cognitive and motivational factors.

1.6 Relationship between eating behaviours, motivation and cognition

Generally, disinhibition and restraint seem to also have an interactive effect with one another on their relationship with BMI (Dykes et al., 2004, Hays et al., 2002, Williamson et al., 1995). However, it also seems that these eating behaviours, as well as hunger, are not only associated with one another, but are also associated with cognitive and motivational factors.

Disinhibition has been shown to be related to greater hedonic hunger (Lowe et al., 2009) and increased impulsiveness (Yeomans et al., 2008, Lyke and Spinella, 2004). Disinhibition has also been shown to be negatively associated with levels of fullness between meals (Barkeling et al., 2007). The combination of a conscious effort to avoid overeating (restraint) with a susceptibility toward overeating (disinhibition) has been suggested to result in more frequent episodes of 'hedonic hunger' (Lowe and Butryn, 2007). However, several studies have found no significant association between TFEQ restraint and hedonic hunger (Yeomans et al., 2008, Lyke and Spinella, 2004, Didie, 2001). In addition, homeostatic hunger has been shown to be associated with external eating; hungry participants scored higher in the external eating scale, but not on the restraint or hunger scales (Evers et al., 2011).

There seems to be a more complex relationship between restraint and hedonic hunger, while one study found no significant association between TFEQ restraint and hedonic

hunger (Didie, 2001), Lowe and colleagues (Lowe et al., 2009) found a positive association between hedonic hunger and the 'Restraint Scale' (Herman C. P., 1980). It seems that, unlike disinhibition, studies have found no significant associations between impulsivity and restraint (Yeomans et al., 2008, Lyke and Spinella, 2004). There have been no studies to date which have investigated the relationship between episodic memory (measured using the Treasure Hunt Task) and eating behaviours. However, one study has shown that memory for the enjoyment of food was related to the level of dietary restraint (Robinson et al., 2011).

Hunger (as measured by the TFEQ) has also been shown to be associated with cognition and motivation. Greater hunger is said to be related to greater hedonic hunger (Lowe et al., 2009). However, one study found that hedonic hunger did not correlated with hunger and appetite, measured by a structured interview in a subgroup of 136 gastric bypass patients (Schultes et al., 2010). In summary, evidence suggests there is a need to further understand how cognitive and motivational factors may influence eating behaviours and their relationship with weight control.

1.7 Thesis overview

The central aim of my thesis is to extend the existing experimental research investigating the relationship between eating behaviours and weight control by examining how cognitive and motivational factors play a role in how eating behaviours influence weight control. This thesis is in two halves. The first part explores eating behaviours and hedonic hunger in the context of relationships and interactions between these measures and weight control in the context of energy intake, as well as weight change during a weight loss intervention and weight maintenance period. In the second half of this thesis I shall

consider the potential mechanisms underlying these behaviours, specifically the cognitive (impulsivity and memory) and motivational factors (hedonic hunger and hunger status) that may control or at least influence food-directed behaviour with the aim of understanding whether, and to what extent, these cognitive and motivational factors contribute to the individual differences in eating behaviours.

To begin investigating the relationship between eating behaviours, motivation and weight control, **Chapter 2** tests whether there is a relationship (and any interactions) between hedonic hunger, restraint and disinhibition with overall energy intake, consumption of perceived healthy or unhealthy foods and consumption of low or high energy density foods. In order to test this, I designed a buffet meal containing 12 foods and 4 drinks which were matched for energy density, but were paired for perceived healthy or perceived unhealthy food/drinks and categorised into low or high energy density. As predicted, this experiment revealed that those with lower restraint was associated with greater energy intake during the ad-libitum buffet. Additionally, those with lower restraint also had higher energy intake from unhealthy foods, but there was no association between restraint and energy intake from healthy foods. Furthermore, lower restraint was also associated with higher energy intake from both high and low energy density foods. My results suggest that restraint is an important factor in energy intake and unhealthy food consumption, but that restraint may not help distinguish between foods of high or low energy density which may be explained by a lack of labelling of calories on the foods (Cavanagh and Forestell, 2013).

Chapter 3 built on the first experimental chapter and examined whether baseline scores and changes in eating behaviours scores were associated with weight control in the

context of changes in weight during an 8-week low-calorie diet and during a 6-month weight maintenance period. In order to investigate this, I used data from the “DioGenes” study carried out in eight European countries (UK, Netherlands, Greece, Germany, Bulgaria, Spain, Denmark and Czech Republic) carried out between 2005 and 2012. My data analysis revealed that lower restraint (but not disinhibition or hunger) at baseline predicted greater weight loss during the 8-week low-calorie diet. These results suggest that people with low dietary restraint appear to benefit from weight loss on liquid formula diets. In addition, this study found no association between changes in eating behaviours and changes in weight during the 8-week low-calorie diet or between changes in restraint or disinhibition during the low-calorie diet with changes in weight during the weight maintenance period. However, this study revealed that decreases in disinhibition and increases in restraint were associated with decreases in weight, during the subsequent 6-month weight maintenance period, which was persistent across all 8 countries. These results demonstrate that weight maintenance interventions which increase restraint and decrease disinhibition may be helpful for individuals after completing a weight loss intervention and may reduce the risk of regaining weight (Wadden et al., 2004). Together, the findings from chapters 2 and 3 revealed that eating behaviours, particularly restraint and disinhibition, may be key factors in understanding overeating and weight control.

I recognised that the eating behaviour measures used in Chapter 2 and 3 were descriptive self-reported questionnaires of how one acts around food and wanted to explore the potential mechanisms underlying these behaviours. Therefore, **Chapters 4 and 5** of my thesis explored specifically the cognitive (impulsivity and memory) and motivational factors (hedonic hunger and hunger status) that may control or at least

influence food-directed behaviour and aimed to investigate how these factors contribute to the individual differences in eating behaviours.

The results of **Chapter 4** suggested that individuals with greater impulsivity, specifically motor impulsiveness (BIS-11 motor subscale) and greater hedonic hunger, specifically when food is present (PFS present subscale), have more disinhibited eating behaviours (TFEQ disinhibition score). These results were further supported by the results of **Chapter 5** which also showed that impulsivity (BIS-11 total score) was positively associated with disinhibited eating as well as all subscales of the power of food scale (hedonic hunger) were positively associated with TFEQ disinhibition in a more diverse group of participants and larger sample size than in Chapter 4. Chapter 4 also revealed that individuals with higher overall impulsivity (BIS-11 total score) had greater levels of hunger (TFEQ hunger score), but I was unable to replicate this in Chapter 5. In addition, Chapter 4 also showed a positive relationship between hedonic hunger (PFS present score) and hunger and restraint TFEQ scores. However, Chapter 5 indicated that the PFS total score was positively associated with TFEQ hunger and restraint scores, however the direction of the association between hedonic hunger and restraint was complex. Chapter 5 also found that those who scored higher on the “what” object recognition recall subtask (for food images only) reported higher TFEQ disinhibition scores, suggesting that those who were better at identifying the image they previously hid during the encoding task are more likely to experience disinhibited eating behaviours, regardless of BMI or dieting status.

This thesis also aimed to explore whether the associations between eating behaviours and BMI are explained by cognitive and motivational factors. Chapter 4 and 5 both

revealed no interactions between any of the eating behaviour, cognitive or motivational variables. However, both studies revealed TFEQ disinhibition was positively associated with BMI, suggesting that those with higher disinhibited eating had a higher BMI. Chapter 4 also found that impulsivity, specifically the BIS-11 motor subscale, was positively associated with BMI. Collectively, the results of these chapters suggest that regardless of age, gender, BMI, IQ and dieting status, impulsivity, hedonic hunger and object recognition episodic memory are important factors in predicting disinhibited eating behaviour and that there seems to be a complex relationship between hedonic hunger and both hunger and restrained eating. In addition, the results also suggest that both motor impulsivity and disinhibited eating behaviours may lead to obesity.

The experiment in Chapter 4 was also designed to test within-subjects the effect of hunger status. In order to test whether there were differences in eating behaviour, cognitive and motivational factors with hunger status in both lean and overweight individuals I designed a study comprised of two sessions for each subject, with one 'fasted' and one 'fed'. My results revealed no significant differences in any of the eating behaviour, cognitive or motivational factors between being fasted or fed, suggesting that completing these measures when hungry or full would not confound the research.

Another aim of my thesis was to replicate the findings from a previous work here in the Department of Psychology (Cheke et al., 2016), which showed a negative relationship between BMI and episodic memory as measured by the treasure-hunt task (THT). Indeed, Chapter 4 found a negative association between BMI and all subtasks of the THT, including spatial, temporal and item memory, as well as the ability to combine these elements ("What-Where-When" memory), whereas Chapter 5 found this same

association in all subtasks except the item memory subtask, which was likely explained by a ceiling effect in the scores of this specific subtask. Given the negative relationship between BMI and episodic memory and studies which suggested that dieting is beneficial to performance on memory tasks (Boraxbekk et al., 2015, Attuquayefio and Stevenson, 2015), another aim of my thesis was to investigate, between-subjects, the effects of dieting on episodic memory (measured using the THT), and whether this interacts with BMI. To test this, in Study 4 (described in Chapter 5) I recruited both lean and overweight individuals who were either currently dieting to lose weight or who were control subjects who were not currently dieting. My results indicated that individuals on a diet, regardless of their BMI, had an impaired performance on the THT compared to those currently not on diet, but there was no interaction between BMI and dieting status on the THT performance.

In Chapter 4, the THT used only food images and therefore the impairment in episodic memory could be suggested to be specific to memory for food items. Therefore, I explored whether an impairment in episodic memory was also seen in the THT when non-food images were used. To test this I created new non-food office stationery item images and re-programmed the THT so that two of the sessions were non-food images and two remained as food tasks so they could be compared. My results from Chapter 5 suggested that participants have a poorer episodic memory for food images compared to non-food images, specifically when recalling the image (“what” subtask) and when integrating all information of what, where and when of the image (“WWW” subtask).

Collectively, the first two experimental chapters (Chapter 2 and 3) of my thesis suggest that increasing an individual’s restrained eating behaviour may be beneficial to weight

control as this may lead to decrease in the consumption of unhealthy foods. In addition, behavioural weight loss maintenance interventions which target decreasing disinhibition and increasing restraint may be useful for weight maintenance following a low-energy/calorie restricted diet. The results also suggest that individuals with lower baseline restraint before dieting appear to benefit most from a liquid formula weight loss intervention. Chapters 4 and 5 suggest that impulsivity, hedonic hunger and object recognition episodic memory are important factors in predicting disinhibited eating behaviour and that hedonic hunger may be an important factor for both hunger and restrained eating behaviours. Furthermore, the variance in disinhibition and motor impulsivity seem to be important factors in the variance of BMI. The implications of these findings are evaluated and discussed in **Chapter 6**. As both studies suggest that BMI and dieting are negatively associated with episodic memory and that individuals overall had a poorer performance on the THT subtasks with food images compared to non-food images, I argue in the final chapter that future work is required to understand the effects of specific diets on episodic memory performance. Tests should be conducted to establish whether there are changes in episodic memory during dieting and if so, the nature and extent of such changes and whether these changes are short-term or remain long after the diet has stopped.

CHAPTER 2

THE RELATIONSHIP BETWEEN EATING BEHAVIOURS, HEDONIC HUNGER AND ENERGY INTAKE DURING AN AD-LIBITUM BUFFET LUNCH¹

Eating behaviours and hedonic hunger have previously been shown to be associated with energy intake. However, it remains to be determined whether eating behaviours, such as disinhibition (external eating) and restraint as well as hedonic hunger are able to predict an individual's intake of healthy vs. unhealthy foods when these foods are matched for energy density. On single occasion, eating behaviours were measured using the Dutch Eating Behaviour Questionnaire (DEBQ), measuring external eating and restraint, and hedonic hunger using the Power of Food scale (PFS) in 63 male and female participants. On the same occasion participants selected and ate food from an ad-libitum buffet, previously rated as healthy or unhealthy foods/drinks, but matched for energy density.

I found that lower restraint was associated with higher total energy consumed during the ad-libitum buffet and greater energy intake from unhealthy foods. However, restraint was not associated with energy intake from healthy foods. Restraint was also

¹ MEDIC, N., ZIAUDDEEN, H., FORWOOD, S. E., DAVIES, K. M., AHERN, A. L., JEBB, S. A., MARTEAU, T. M. & FLETCHER, P. C. 2016. The Presence of Real Food Usurps Hypothetical Health Value Judgment in Overweight People. *eNeuro*, 3.

negatively associated with energy intake from both high and low energy density foods. My results suggest that restraint is an important factor when making unhealthy (but not healthy) food choices as well as overall consumption. In conclusion, further work is required to understand whether eating behaviours are associated with weight control outside the laboratory in a more real-world setting and over a longer period, for example, whilst dieting to achieve weight loss and subsequent weight maintenance.

2.1 Introduction

Despite individuals living in the same culture and exposed to a similar “obesogenic” environment, some individuals gain weight while others do not (French et al., 1995). Overconsumption of food is a contributing factor to this susceptibility to weight gain (Blundell and Finlayson, 2004). This variability in overconsumption may be attributed to individual differences in eating behaviours, such as disinhibition, external eating and restraint. In order to measure these individual differences in eating behaviours, researchers have developed self-report questionnaires, such as the Three-Factor Eating Questionnaire (TFEQ) constructed by Stunkard and Messick in 1985 (Stunkard and Messick, 1985) and the Dutch Eating Behaviour Questionnaire (DEBQ: (van Strien et al., 1986)). Since their development these questionnaires have been used in several studies to investigate their relationship with food consumption and food choice.

Previous studies have shown that individuals with high disinhibition scores tend to have higher energy intake. One study showed that higher disinhibition scores were associated with consumption of more ice cream in a laboratory setting (Westenhoefer et al., 1994). Whereas other studies reported higher energy intake over 3-days based on food records (Provencher et al., 2003) and food frequency questionnaire (Lindroos et al., 1997).

Unlike disinhibition, the relationship between restraint and energy intake is a little less straight forward. Several studies have reported a negative association between restraint and overall energy intake (Laessle et al., 1989a, French et al., 2014, De Castro, 1995, Provencher et al., 2003, Lindroos et al., 1997). Despite these studies suggesting a negative association between restraint and energy intake, the relationship between restraint and energy intake is complex as it seems the associations tend to vary by age, gender and BMI. For example, one study showed that restrained eaters had a greater increase in eating rate which led to a greater overall consumption compared to unrestrained eaters (Thompson et al., 1988). Studies following this, however, found no association between the TFEQ restraint scale score and consumption of food (Tuschl et al., 1990a, Smith et al., 1998, Westenhoefer et al., 1994). Furthermore, a small number of studies have shown that disinhibition/external eating and restraint have an additive effect on energy intake. Individuals with both high disinhibition/external eating and low restraint had a higher energy intake compared with those who had both low disinhibition/external eating and high restraint, who had a lower total energy intake (Westenhoefer, 1991, Westenhoefer et al., 1994).

While there is a body of evidence to suggest eating behaviours are important factors in overall energy intake, it seems that eating behaviours may also be important for healthy food choices and consumption. One study has shown that individuals with high restraint ate more healthful brand labelled cookies than when they were presented with the less healthy brand labelled cookies. However, they also showed that participants with low restraint had no difference in their intake between healthy and unhealthy brand labelled cookies (Cavanagh and Forestell, 2013). Other studies have used food diaries to investigate food choice and have shown mixed results in the relationship between

eating behaviours and healthy food choice. On the one hand, some studies have shown that adults with high restraint generally chose more healthful food choices and reported higher energy intake from healthy foods, such as fruit, vegetables and chicken and lower energy intake from unhealthy foods, such as cheese, ice cream, cakes and soda drinks (Contento et al., 2005, De Castro, 1995). Some studies have found little differences in healthy food choice between restrained and unrestrained eaters, however there was a slight trend towards fewer high-sugar or high-fat foods being eaten by restrained eaters (Tuschl et al., 1990a, French et al., 1994). These studies suggest a complex relationship between restrained eating behaviour and healthful food choice, whereas disinhibition/external eating has been shown to have a positive association with more unhealthy food choices. Studies have shown that individuals with high disinhibition/external eating reported a higher consumption of unhealthy foods, such as ice cream, butter, foods high in fat and sweet carbonated drinks (Contento et al., 2005, Lahteenmaki and Tuorila, 1995). Studies have also shown that the energy content of foods may be associated with eating behaviours. A study which labelled cookies as low-calorie or high-calorie, found that individuals with high restraint ate more of the healthy branded cookies when they were labelled as low-calorie than when they were labelled as high-calorie. Individuals with low restraint ate more of the healthy branded cookies regardless of the calorie label condition (Cavanagh and Forestell, 2013). Another study which used a food diary to report food intake over 7 days also found that those with high restraint preferred low energy, healthy foods and reported less energy dense food items (Laessle et al., 1989a). Thus, it seems disinhibition/external eating and restraint play important roles, not only in overall food intake, but in healthy and low-energy-dense food choices.

Research has shown that eating behaviours are associated with energy intake, however, more recently it has been shown that motivational factors, such as hedonic hunger, may also influence consumption. Hedonic hunger has been described as the tendency to experience thoughts, feelings and urges about food in the absence of any short- or long-term energy deficit (Lowe and Butryn, 2007). A commonly used self-report questionnaire for hedonic hunger is the Power of Food Scale (PFS; (Lowe et al., 2009)). The PFS and the DEBQ External Eating Scale have been shown to be positively correlated (Lowe et al., 2009). However, the PFS differs from the DEBQ External Eating Scale because the PFS measures the hedonic drive to eat as opposed to the actual eating behaviour. Hedonic hunger has been shown to be associated with consumption of food. Those who had a higher hedonic hunger score were more likely to eat a box of chocolates rather than keeping them for 48 hours (Forman et al., 2007). However, it remains to be considered whether eating behaviours and hedonic hunger are able to predict an individual's overall energy intake and energy intake from healthy vs. unhealthy foods when these foods are matched for energy density. It also remains to be determined whether these eating behaviours and hedonic hunger have an interactive effect on this association.

2.2 Aims and Hypotheses

Aims	Hypotheses
Primary	
To investigate the relationship (and any interactions) between hedonic hunger, restraint and external eating on energy intake from an ad-libitum buffet.	I predicted that external eating and hedonic hunger would have a positive association with overall food intake, whereas there would be a negative association between restraint and total energy consumed during the ad-libitum buffet meal. It was also predicted that there may be an interaction between restraint and external eating on total energy consumed.
Secondary	
To examine the association between hedonic hunger, restraint and external eating (and any interactions) and total energy intake from pre-defined healthy and unhealthy foods which were matched for energy density in an ad-libitum buffet.	I predicted that there will be a positive association between restraint and energy intake from healthy foods and a negative association between restraint and energy intake from unhealthy foods. It is also predicted that both external eating and hedonic hunger will be negatively associated with energy intake from healthy foods and positively associated with energy intake from unhealthy foods in the buffet meal.
To explore the association between hedonic hunger, restraint and external eating (and any interactions between) and total energy intake from pre-defined high and low energy dense foods in an ad-libitum buffet.	I predicted that there will be a positive association between restraint and energy intake from low-energy density foods and a negative association between restraint and energy intake from high-energy density foods. It is also predicted that both external eating and hedonic hunger will be negatively

	associated with energy intake from low-energy density foods and positively associated with energy intake from high-energy density foods in the buffet meal.
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2.3 Methods

Participants

Healthy male and female participants (aged 18-40 years, mean = 30.1 years; 30 males: 39 females) were recruited to the study through adverts, flyers, posters and social media. These individuals were separated into three groups: lean (BMI <25kg/m²), overweight (BMI >25kg/m²) and obese (BMI >30kg/m²) and were matched for age, gender, socioeconomic status (SES) and IQ.

All participants had no history of psychiatric or other significant medical history. Individuals who participated in more than three hours of exercise per week were excluded to try and prevent falsely including athletes whose BMI may be higher, due to increased muscle mass and placing them in the overweight category. Vegetarians and those with allergies or dietary preferences to the food items used in the study were also excluded. In order to ensure the sample of participants were representative of the UK population, participants were recruited from the wider community rather than exclusively from the University of Cambridge.

In order to dissociate the group differences in eating behaviour, hedonic hunger and energy intake from the potential confound of socioeconomic status, effort was made to recruit individuals across lean, overweight and obese groups with a comparable variability in education level and yearly income. This is particularly important as lower

socioeconomic groups have a greater prevalence of being overweight and obesity (National Obesity Observatory, 2012).

Five participants did not complete the study and were excluded from the analysis. One further individual was excluded after being identified as taking part in rigorous physical training (body building), which was not detected during the screening procedure. Therefore, I performed analysis on the remaining 63 participants.

Study design

The study was approved by the University of Cambridge Psychology Research Ethics Committee and was conducted at the Institute of Public Health department and Psychiatry department. Full details of the study design can be found in the published methods within Medic et al., (Medic et al., 2016). However, for the purpose of this thesis I will discuss the design and measures used in my portion of the study only. On the day of the study participants were instructed to eat their normal breakfast at home before 8am. The study session started at approximately 9am and ran in the same order for all participants over 1 day. All participants provided written, informed consent. The buffet was served between 1-1:30pm and behavioural questionnaires were administered to participants using an online platform following the buffet, as shown in Figure 1.

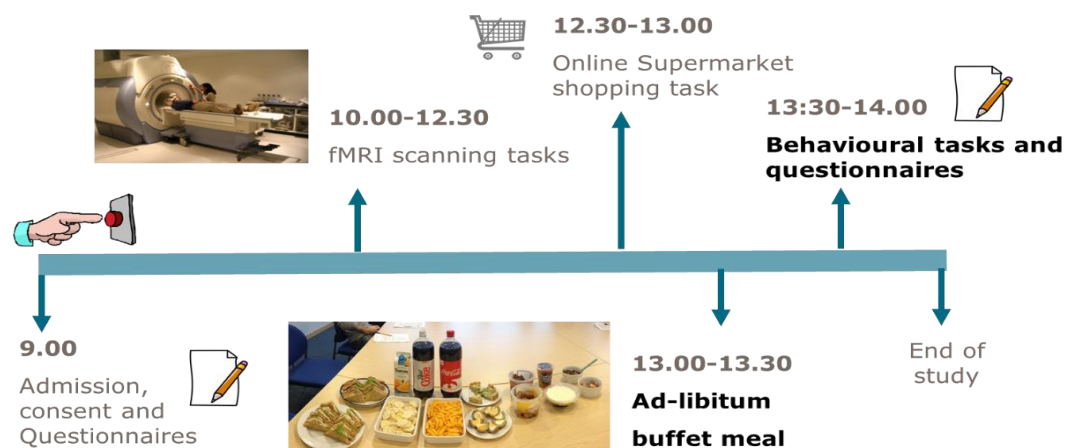


Figure 1: Study design for the whole study day, highlighting the measures taken in my portion of the study.

Questionnaires

Dutch Eating Behaviour Questionnaire (DEBQ)

Restraint and external eating were measured using the DEBQ (van Strien et al., 1986).

The DEBQ consists of 33 items with answers on a 5-point Likert scale which ranged from “never” to “very often”. This questionnaire contains items for three different eating behaviours defined by Van Strien et al. (van Strien et al., 1986) based on psychological theories: external eating, restrained eating and emotional eating. The “externality theory” (Rodin, 1981, Schachter et al., 1968) is described as eating in response to food-related stimuli (e.g. the sight or smell of food) with a disregard to one’s internal state of hunger and satiety (e.g. external eating, one component of disinhibition). The theory of “restrained eating” (Herman and Polivy, 1975) is the degree of conscious food restriction in order to lose or maintain a particular weight (e.g. restraint subscale). The “psychosomatic theory” (Kaplan and Kaplan, 1957) emphasizes the role of “emotional eating” (e.g. emotional eating scale), which was not analysed in this study. The questionnaire can be found in Appendix 1.

Power of Food Scale (PFS)

The PFS is a 15 item self-report scale which measures hedonic hunger (Lowe et al., 2009). It consists of three sub-scales that are designed to assess an individual's responsiveness to food when it is: not present (e.g., "I find myself thinking about food even when I'm not physically hungry."), present (e.g., "If I see or smell a food I like, I get a powerful urge to have some."), or tasted (e.g., "Just before I taste a favourite food, I feel intense anticipation."). Higher scores indicate greater hedonic hunger. The PFS has demonstrated adequate test-retest reliability, incremental validity, and internal consistency (Lowe et al., 2009, Cappelleri et al., 2009). The questionnaire can be found in Appendix 2.

Test of G

The test of G (Cattell, 1950) is a non-verbal intelligence test which minimizes culture or education biases. The test is based on image patterns and the questions increase in difficulty with the order of questions.

Ad-libitum Buffet

Each participant was offered an ad-libitum buffet consisting of an excess total number of calories (approximately 10,249 kcal), as shown in Table 2.1. I instructed each participant to "eat as little or as much as they liked" and left them alone for approximately 30 minutes. The foods and drinks in the ad-libitum buffet were selected from the food/drinks coding database used in the National Diet and Nutritional Survey carried out at the Human Nutrition Research unit (Whitton et al., 2011). Six of the foods were classed as high energy density foods with greater than 250kcal/100g and six of the foods were classed as low energy density by having less than 250kcal/100g. The four drinks were classed as high energy density if they had higher than zero kcal/100g (two

drinks) and were classed as low energy density if they had zero kcal/100g (two drinks), as shown in Table 2.1. These foods and drinks were paired for perceived healthy and perceived unhealthy (as pre-determined by a survey carried out by Suzanna Forwood at the Institute of Public Health) and these pairs of foods and drinks were closely matched in energy density.

Statistical analysis

Comparison of baseline differences of eating behaviours and hedonic hunger between gender and group were made using Student's T test or one-way ANOVAs, respectively. Pearson's correlation analyses, corrected for multiple comparisons using the Sidak's correction method (Šidák, 1967) were performed to investigate the relationship between the DEBQ measures and PFS scores.

In order to investigate the association between energy intake from the buffet and eating behaviours/hedonic hunger, linear regression models were used with energy intake entered into each model as dependent variables and all eating behaviour and hedonic hunger scores as the independent variables. The StepAIC function from the MASS package in R was used to select the best model fit by minimizing Akaike's information criterion (AIC) (Venables, 2002). Forward and backward model selections were implemented to allow for interactions between variables. Given that during recruitment the lean, overweight and obese groups were matched for age, gender, socioeconomic status and IQ, all best-fit models from the stepAIC selection process were adjusted for BMI only. An interaction term between BMI and each independent variable was also investigated in the model. Further analysis was performed by adding an interaction term between external eating, restraint and hedonic hunger for each of the models to

investigate the interactive effect these variables may have on the dependent variable in the model. Analyses were performed using the R statistical programme (R, 2008) (Version 3.1.2, R).

Table 2.1: Buffet food/drink nutritional content and total number of calories served													
Perceived unhealthy							Perceived healthy						
	Food	kcal/100g	Fat /100g	Sat fat/100g	Weight /Volume as served	Calories available		Food	kcal/100g	Fat /100g	Sat fat/100g	Weight/Volume as served	Calories available
High Energy density	Cheddars crackers	509	27.7	16	200g	1018	High Energy Density	Oatcake crackers	449	21.8	8.4	200g	898
	Chocolate rolls	454	22.2	13.6	200g	908		Eat natural cereal bar	456	24.7	16.4	200g	912
	Fruit pastille sweets	330	trace	0	100g	330		Dried mixed fruit	280	0.6	0.2	100g	280
	Coke	42	0	0	1 litre	420		Orange juice	48	0	0	1 litre	480
Low energy density	Scotch eggs	235	15.3	8	400g	940	Low energy density	Broccoli and tomato quiche	215	13.2	4.3	400g	860
	BLT Sandwich	225	10	2.2	354g	797		Chicken Salad Sandwich	195	7.5	1	400g	780
	Trifle	160	5.4	3.4	600g	960		Strawberry Yogurt	111	2.6	1.7	600g	666
	Diet coke	0	0	0	1 litre	0		Water	0	0	0	1 litre	0

2.4 Results

Demographic associations

The demographic characteristics of the 63 participants are shown in Table 2.2. As expected there were significant differences in weight and BMI between groups but they were matched for age, gender, socioeconomic status and IQ. Of the 63 individuals, 56 were white (European/US), 3 were Black (African/Caribbean/other) and 4 were Asian (Indian).

Table 2.2: Mean (Standard Deviation) demographics for each group and ANOVA results						
Variable	Lean (n=21)	Overweight (n=22)	Obese (n=20)	All (n=63)	Difference between groups F-value/ χ^2 * (df=2)	P-value
Age (years)	30.7 (5.6)	30.3 (6.2)	30.3 (5.8)	30.40 (5.8)	0.03	0.967
Weight (kg)	66.9 (9.6)	78.0 (7.8)	101.5 (13.7)	81.8 (17.7)	57.2	<0.001
BMI (kg/m²)	21.9 (1.33)	27.4 (1.33)	34.9 (4.58)	28.0 (5.98)	111.1	<0.001
IQ (Test of G score)	107.86 (12.95)	109.91 (18.87)	111.79 (15.44)	109.79 (15.83)	0.3	0.741
Gender (M:F)	9:12	10:10	9:13	28:35	0.38	0.826

There were no significant differences between the lean, overweight and obese groups in any of the eating behaviour or hedonic hunger measures using ANOVA analysis, as shown in Table 2.3. Welch two sample student's T-tests also revealed no significant differences in behavioural measures between men and women. Pearson's correlation

analysis revealed a significant positive relationship between DEBQ restraint score and BMI, as shown in Table 2.3. However, there were no other significant correlations between any of the eating behaviour or hedonic hunger measures and BMI.

Table 2.3: Mean and (standard deviation) for eating behaviour and hedonic hunger for each group and differences between groups, gender and correlation with BMI							
Variable	Lean	Over-weight	Obese	All	Difference between groups	Difference between Gender	Correlation with BMI
					F-value; (P-value) ^a	T-value (P-value) ^b	r-value (P-value) ^c
DEBQ External Eating	30.52 (4.59)	32.86 (5.63)	31.10 (7.04)	31.52 (5.81)	0.95 (0.393)	0.413 (0.682)	0.047 (0.715)
DEBQ Restrained	23.19 (8.41)	25.14 (6.34)	27.85 (4.87)	25.35 (6.88)	2.48 (0.092)	1.482 (0.144)	0.306 (0.015)
PFS Total	2.44 (0.61)	2.51 (0.78)	2.56 (0.83)	2.50 (0.73)	0.15 (0.864)	-0.187 (0.852)	0.137 (0.285)
PFS Present	2.38 (0.77)	2.70 (0.92)	2.73 (1.04)	2.60 (0.91)	0.93 (0.399)	-0.170 (0.865)	0.019 (0.884)
PFS Available	2.09 (0.84)	2.27 (0.94)	2.28 (0.94)	2.21 (0.90)	0.31 (0.735)	0.458 (0.649)	0.149 (0.243)
PFS Tasted	2.90 (0.78)	2.63 (0.74)	2.77 (0.75)	2.77 (0.75)	0.73 (0.488)	-1.049 (0.299)	0.172 (0.179)
a= ANOVA, differences between groups; b=Welch two sample T-tests, differences between gender; c=Pearson's correlation analysis, relationship with BMI							

Relationship between eating behaviour and hedonic hunger scores

Pearson's correlation analysis, corrected for multiple comparison using Sidak's correction(alpha changed from 0.05 to 0.009) revealed that external eating and restraint

scores were not significantly associated with one another, however without Sidak's correction there was a trend towards significance ($r=0.238$, $p=0.060$) with higher external eating scores being associated with higher restraint scores, as shown in Figure 2.1a. PFS total scores and external eating scores had a significant positive association ($r=0.618$, $p<0.001$), therefore higher PFS total scores were associated with higher external eating scores (Figure 2.1b). There was no association between PFS total and DEBQ restraint scores ($r=0.194$, $p=0.128$). Of the PFS subscales, DEBQ external eating scores were positively associated with PFS tasted scores ($r=0.458$, $p<0.001$), PFS available ($r=0.504$, $p<0.001$) and PFS present ($r=0.645$, $p<0.001$). Thus, greater external eating scores were associated with higher PFS tasted, available and present scores, as shown in figure 2.1c, d and e. DEBQ restraint score was only associated with PFS present score ($r=0.309$, $p=0.014$), as shown in Figure 2.1f. As expected, there were significant positive correlations between the PFS total score and its subscales (PFS total~available: $r=0.912$, $p<0.001$; PFS total~present: $r=0.793$, $p<0.001$; PFS total~tasted: $r=0.847$, $p<0.001$) as well as between the subscales (available~present: $r=0.575$, $p<0.001$; available~tasted: $r=0.675$, $p<0.001$; tasted~present: $r=0.524$, $p<0.001$). There were no other associations between any of the PFS subscale scores and restraint scores.

Energy intake during buffet

Overall, individuals ate on average a lunch of 1194 kcal (4996KJ), of which an almost even split between perceived unhealthy foods (51%) and perceived healthy foods (49%) were consumed. However, there was a difference in the percentage of high energy density foods (34%) and low energy density foods (66%) consumed. There were no

significant differences between groups in buffet consumption, as shown in Table 2.4. Welch two sample t-tests, also shown in Table 2.4, revealed that energy intake among men was greater than women (1444 vs 994 kcal; $p = <0.001$). Men also had higher energy intake from unhealthy foods than women (442 vs 866kcal; $p=<0.001$). Men also had higher energy intake from low energy dense foods in comparison to women (629 vs. M: 986 kcal; $p=<0.001$), as shown in Table 2.4. There were no other significant differences in food consumption between genders.

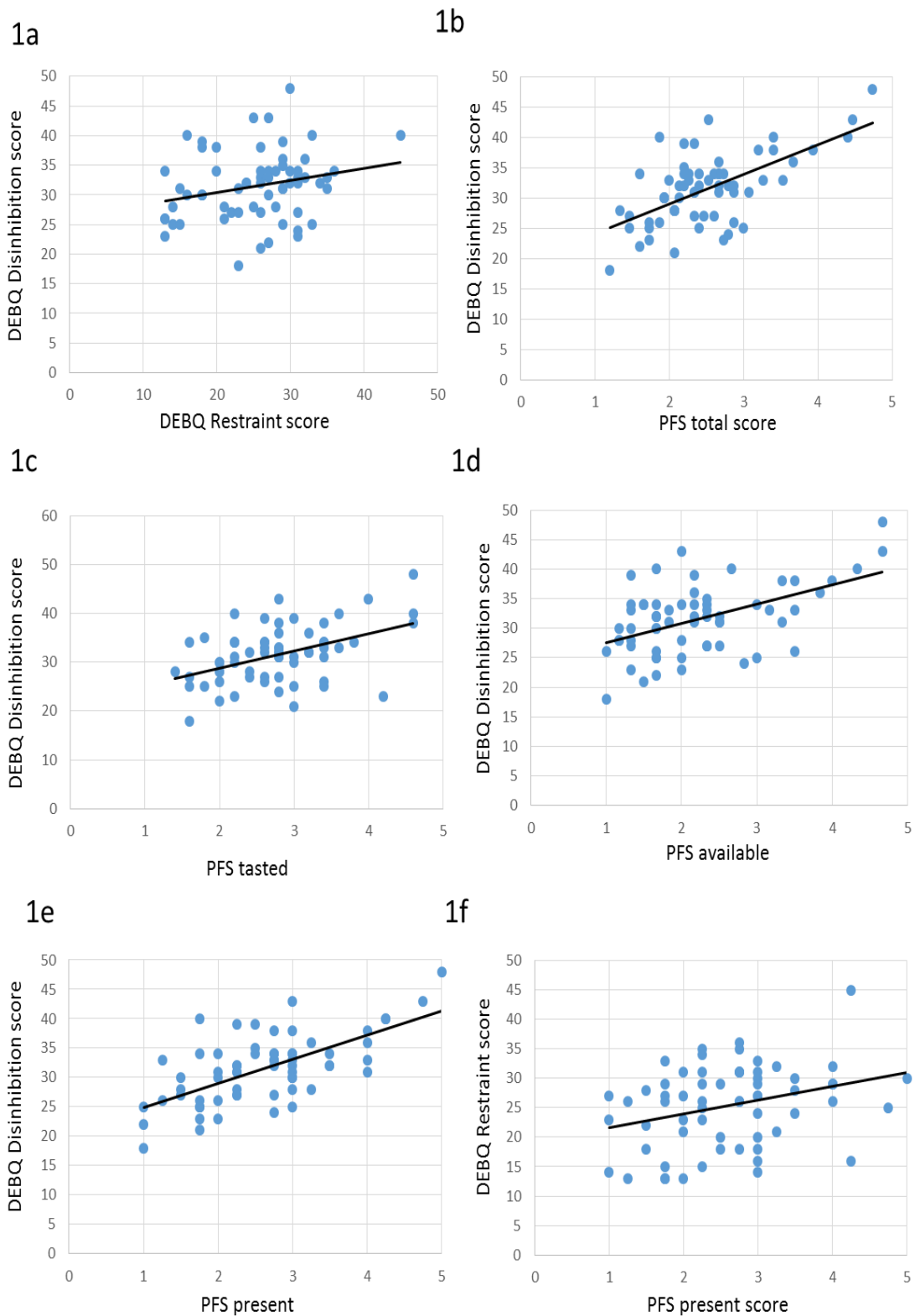


Figure 2.1: Correlation plots between eating behaviour and hedonic hunger

Table 2.4: Mean (SD) energy intake from buffet and ANOVA results							
Variable	Lean	Over-weight	Obese	All	Difference between groups F-value; df=2 (P-value)^a	Difference between Gender T-value (P-value)^b	Correlation with BMI r-value; df=61 (P-value)^c
Total energy eaten (kcal)	1142 (591)	1196 (445)	1246 (424)	1194 (486)	0.23 (0.797)	-4.080 (<0.001)	0.005 (0.971)
Energy intake from healthy foods (kcal)	671 (383) 58%	474 (267) 41%	550 (290) 47%	564 (323) 49%	2.10 (0.132)	-0.322 (0.749)	0.027 (0.835)
Energy intake from unhealthy foods (kcal)	472 (312) 42%	723 (404) 59%	696 (393) 53%	631 (383) 51%	2.90 (0.063)	-5.034 (<0.001)	0.029 (0.824)
Energy intake from high energy density foods (kcal)	350 (210) 33%	431 (235) 34%	441 (265) 34%	407 (237) 34%	0.93 (0.402)	-1.560 (0.124)	0.002 (0.988)
Energy intake from low energy density foods (kcal)	793 (485) 67%	766 (300) 66%	805 (308) 66%	787 (369) 66%	0.06 (0.941)	-4.218 (<0.001)	0.005 (0.969)
a= ANOVA, differences between groups; b=Welch two sample T-tests, differences between gender; c=Pearson's correlation analysis, relationship with BMI							

Relationship between eating behaviours, hedonic hunger and energy intake

To investigate the relationship between eating behaviours and hedonic hunger with energy intake during the buffet, five linear regression analyses were conducted. Models 1 assessed the extent to which eating behaviours and hedonic hunger predicted total calorie intake in the buffet: the total number of calories was entered as the dependent variable and all eating behaviours and hedonic hunger scores (and interactions between them) were entered as independent variables. Models 2 and 3 assessed the extent to which eating behaviours and hedonic hunger predicted energy intake of healthy or unhealthy foods: the total calories of healthy or unhealthy foods were entered as dependent variables in each model and all eating behaviours and hedonic hunger scores (and interactions between them) were entered as independent variables. Finally, models 4 and 5 assessed the extent to which eating behaviours and hedonic hunger predicted energy intake from high energy or low energy dense foods: the total calories of high- or low-energy dense foods were entered as dependent variables in each model and all eating behaviours and hedonic hunger scores (and interactions between them) were entered as independent variables. Given that during recruitment the lean, overweight and obese groups were matched for age, gender, socioeconomic status and IQ, all best-fit models from the stepAIC selection process were adjusted for BMI only.

As shown in table 2.5, in model 1, overall energy intake was best fit by a model containing the DEBQ restraint and the PFS present scores, which predicted 17% of the variance in total calories consumed. However, the DEBQ restraint score was the only one to be significantly negatively associated with total energy intake. Those with lower restraint scores had a greater amount of energy intake, as shown in figure 2.2. There was no significant interaction between external eating, restraint and hedonic hunger on

total energy intake. There was also no interaction between BMI and restraint on the total energy intake.

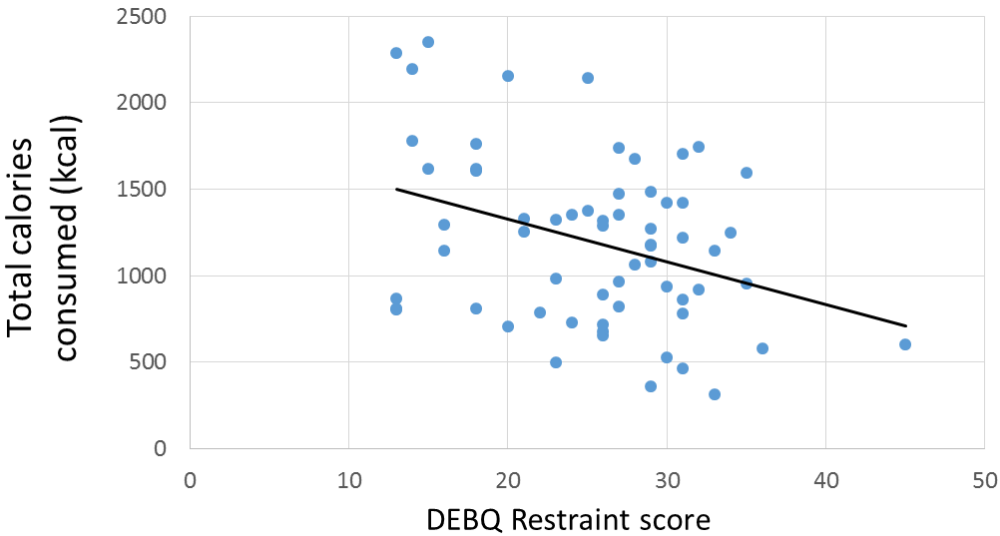


Figure 2.2: Correlation plot to show the relationship between restraint score and total energy intake (total calories) from the buffet

Table 2.5: Regression models for the association between eating behaviour measures and buffet consumption

Model (Dependent variable)	R ²	Adj. R2	Independent variable	β (SE)	T-value	P- value
Model 1: Overall energy intake (kcal)	0.17	0.12	DEBQ restraint	-31.114 (9.18)	-3.389	0.001
			PFS present	96.910 (66.82)	1.450	0.152
Model 2: Energy intake from perceived unhealthy foods (kcal)	0.13	0.09	DEBQ restraint	-20.980 (7.37)	-2.845	0.006
			PFS present	92.129 (53.67)	1.716	0.091
Model 3: Energy intake from perceived healthy foods(kcal)	0.04	0.01	DEBQ restraint	-9.954 (6.23)	-1.599	0.115
Model 4: Energy intake from high energy density foods (kcal)	0.11	0.07	DEBQ restraint	-11.270 (4.62)	-2.437	0.018
			PFS present	60.430 (33.66)	1.795	0.078
Model 5: Energy intake from low energy density foods (kcal)	0.11	0.08	DEBQ restraint	- 18.474(6.86)	-2.692	0.009
All models were controlled for BMI (kg/m ²)						

Relationship between eating behaviour and hedonic hunger and energy intake from pre-defined healthy and unhealthy foods

In model 2, the best fit model for energy intake from perceived unhealthy foods contained the DEBQ restraint and PFS present scores, which predicted 13% of variance in energy intake of unhealthy foods. Again, only the DEBQ restraint score was negatively

associated with the energy intake from perceived unhealthy foods. Lower restraint scores were associated with a greater energy intake from unhealthy foods from the buffet, as shown in figure 2.3. In model 3, energy intake from perceived healthy foods was best fit by a model which only contained the DEBQ restraint score, which predicted 4% of the variance in energy intake. However, DEBQ restraint score was not significantly associated with the energy intake from perceived healthy foods. There was no significant interaction between external eating, restraint and hedonic hunger on the dependent variables in both of the models. There was also no interaction between BMI and restraint on the energy intake from perceived healthy and unhealthy foods.

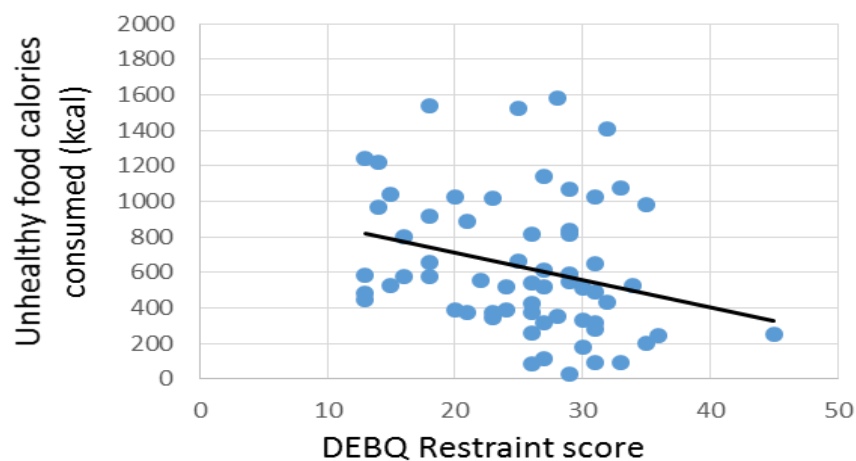


Figure 2.3: Correlation plot to show the relationship between restraint score and energy intake from unhealthy foods in the buffet

Relationship between eating behaviour and hedonic hunger measures and energy intake from low and high energy density categorised foods

In model 4, the best fit model for energy intake from high energy density foods contained the DEBQ restraint and PFS present scores, and predicted 11% of variance of energy intake. Only the DEBQ restraint score was negatively associated with the energy

intake from high energy density foods in the buffet. Lower restraint scores were associated with a greater energy intake from high energy density foods from the buffet, as shown in figure 2.4.

In model 5, energy intake from low energy density foods was best fit by a model which only contained only the DEBQ restraint score, which predicted 11% of the variance in energy intake. Like the previous model, DEBQ restraint score was also negatively associated with energy intake from low energy density foods. Lower restraint scores were associated with a greater energy intake from low energy density foods from the buffet, as shown in figure 2.4. There was no significant interaction between external eating, restraint and hedonic hunger on the dependent variables in both of the models. There was also no interaction between BMI and restraint on the energy intake from low or high energy density foods.

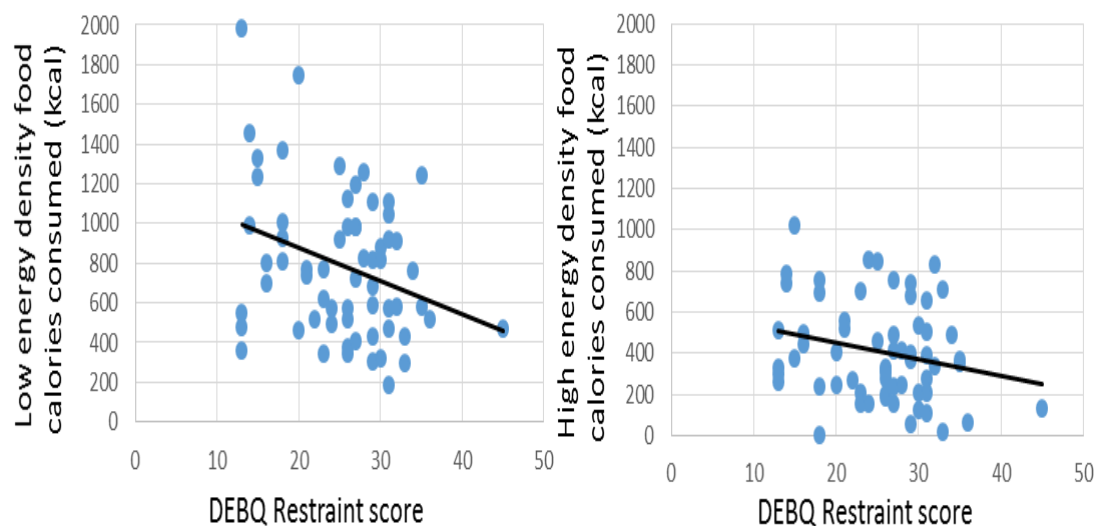


Figure 2.4: Correlation plot to show the relationship between restraint score and total energy intake from low energy density and high energy density foods

2.5 Discussion

The main aim of this study was to investigate the relationship (and any interactions) between hedonic hunger, restraint and external eating on total energy intake during an ad-libitum buffet lunch. My results revealed a negative association between DEBQ restraint score and total energy intake during the ad-libitum buffet, suggesting that those with lower restraint scores had a greater energy intake than those with higher restraint scores. This result is in line with several studies which have also shown that individuals with low-restraint reported higher levels of overall energy intake compared to those with high-restraint, despite different methods of recording energy intake by using a 3 to 7-day food diary (Laessle et al., 1989a, De Castro, 1995, Provencher et al., 2003), telephone dietary recalls (French et al., 2014) or a validated food frequency questionnaire (Lindroos et al., 1997). However, my results are contrast to several studies which have shown either a positive association or no association between restrained eating behaviour and food consumption. One study showed that restrained eaters had a greater increase in eating rate which led to a greater overall consumption compared to unrestrained eaters (Thompson et al., 1988). Whereas, no association was seen between the TFEQ restraint scale score and consumption of basic foods and snacks (Tuschl et al., 1990a), ice cream (Westenhoefer et al., 1994) or a macaroni and beef meal (Smith et al., 1998) in women. My results may differ to these previous studies because my study included both men and women and used a variety of foods in a buffet lunch. While my results suggest that, regardless of BMI, an individual's level of restrained eating behaviour is important for predicting food intake, the relationship between restrained eating behaviour and food intake is unclear.

While my study revealed no association between external eating and total energy intake during the ad-libitum buffet meal, previous studies have found a consistent positive association between disinhibition/external eating and energy intake. Studies have shown that individuals with high disinhibition/external eating scores consumed more ice cream (Westenhoefer et al., 1994) and reported higher energy intake over a 3-day food record (Provencher et al., 2003) and a food frequency questionnaire (Lindroos et al., 1997). This is possibly explained by the fact that there was no “external eating” in this study because all of the choices and food eaten were in a laboratory setting. The method used (an ad-libitum buffet) is possibly problematic because, despite not telling a participant that their food would be weighed before and after, the transparency of being in the “laboratory” may affect the amount a participant consumes due to self-presentation concerns (Robinson et al., 2013a, Robinson et al., 2014, Robinson et al., 2016). Furthermore, although a small number of studies showing that individuals with both high disinhibition and low restraint was associated with higher energy intake (Westenhoefer, 1991, Westenhoefer et al., 1994), my study found no interaction between external eating and restraint on total calories consumed. The results of this study also showed no relationship between hedonic hunger and intake, despite the PFS present scale remaining in the best-fit model for total calories consumed there was no significant association between the two variables. This is contrast to one previous study that found a relationship between hedonic hunger and food intake. All participants in the study were given a box of chocolates and told not to eat them for 48 hours, those with higher hedonic hunger were more likely to eat the chocolates than those who had lower hedonic hunger score (Forman et al., 2007). These differences in results may be explained by the nature of testing energy intake. My study was cross-sectional and set

in a laboratory with a variety of food to mimic a buffet lunch, whereas the majority of the other studies were either eating or recording what they ate in the real world or measuring energy intake using a bogus taste test and as such may yield different results due to the methods used during these studies. These results therefore suggest that more research is required to fully understand the relationship between these measures of external eating and hedonic hunger and food intake.

A secondary aim of this study was to investigate the relationship (and any interactions) between hedonic hunger, restraint and disinhibited eating and energy intake from perceived healthy or unhealthy foods. My results revealed that lower reported DEBQ restraint scores were associated with greater total calories of perceived unhealthy foods consumed. However, it seems this relationship is not bi-directional as DEBQ restraint scores were not associated with total calories of perceived healthy foods consumed. These results suggest that regardless of BMI, impairments in dietary restraint may facilitate the consumption of perceived unhealthy foods. Very few studies have investigated the relationship between eating behaviours and energy intake from perceived healthy or unhealthy foods. However, one study investigated the relationship between healthy and unhealthy brand labelling and consumption in restrained and unrestrained women (Cavanagh and Forestell, 2013). In contrast to my results, they found that restrained eaters (determined by the TFEQ restraint score) ate more of the ad-libitum cookies labelled with a healthful brand than when they were exposed to the less healthy brand of cookies. They also found no difference in energy intake between the healthy and unhealthy branded cookies in unrestrained eaters (Cavanagh and Forestell, 2013). While my study, to my knowledge, is unique in matching pre-defined healthy and unhealthy foods in a food consumption test, there are studies which have

investigated the relationship between eating behaviours and healthful food choices. One study found that Caribbean Latina women with high restraint generally chose more healthful food choices and as such had higher intake of perceived healthy foods (e.g. fruits, vegetables, and low-fat dairy products and chicken) and lower intake of perceived unhealthy foods (e.g. cream, ice cream, cakes, and sodas) (Contento et al., 2005). Another study found that in 358 free-living adults, those who had high restraint reported eating significantly less beef and cheese and more fruit and chicken as well as drinking fewer sugary beverages and more artificially sweetened diet drinks compared to those with low restraint using a 7-day food diary. Thus, higher restraint was associated with lower food intake, especially of fat and sugar (De Castro, 1995) . However, two other studies found very few differences between restrained and unrestrained eaters, however there was a slight trend towards fewer high-sugar or high-fat foods being eaten by restrained eaters (Tuschl et al., 1990a, French et al., 1994). Overall, these studies suggest an unclear relationship between restrained eating behaviour and quality of diet, however, they do, like my results, suggest that restrained eaters may choose foods which are more healthful.

While it seems, restrained eating is associated with more healthful food choices, previous literature has also shown that disinhibition/external eating is associated with more unhealthy food choices. Despite my results revealing no association between external eating or hedonic hunger and consumption of perceived healthy or unhealthy foods, other cross-sectional studies have shown that individuals with high disinhibition/external eating are more likely to report a higher consumption of sweet foods, ice cream, butter and coffee (Lahteenmaki and Tuorila, 1995) and more likely to choose high-fat foods, foods high in fat and salt, processed meat, sweet fruits and

vegetables, and sweet, carbonated drinks (Contento et al., 2005). Although my study showed no relationship between external eating and energy intake from healthy or unhealthy foods, the literature suggests that disinhibition/external eating is associated with greater choice and consumption of unhealthy foods. This result once again may be explained by this study being conducted in a laboratory setting with only a finite amount of food choice from the buffet and does not mimic the real-world environment.

Another secondary aim of this study was to investigate the relationship (and any interactions) between hedonic hunger, restraint and external eating with energy intake from pre-defined high or low energy density foods. My results revealed that restraint was negatively associated with both high and low energy density foods consumed. This suggests that lower restrained eating behaviour is important in both the consumption of high and low energy dense foods. However, it may be that the participants in this study were unable to distinguish between foods of high or low energy density as the foods they were presented with were unlabelled. Studies to support this have suggested that unhealthy branded foods could be viewed as more attractive when labelled as having a lower energy content (Cavanagh, 2014). Cavanagh and colleagues also reported that participants in general ate more cookies when exposed to the low-calorie label in comparison to the exposure to high-calorie label and the no label. Furthermore, restrained eaters ate more cookies in the less healthy brand condition when they were exposed to a low-calorie label compared to a high-calorie label. However, unrestrained eaters ate more cookies in the healthful brand condition, regardless of calorie labels (Cavanagh and Forestell, 2013). Another study showed that restrained eaters recorded (over 7 days) avoiding calorie dense food items of high carbohydrate and fat content, instead preferring low-caloric and healthy foods (Laessle et al., 1989a). Therefore,

although my study revealed that restraint was associated with both high and low energy density foods, it seems restrained eaters are also sensitive to calorie labelling on foods. However, energy content seems to be less important to restrained eaters when perceiving that the food is from a healthy food company. Given my study had no labelling on the ad-libitum buffet this may explain why those with low restraint consumed more of both the high and low energy density foods.

The strength of this study lies in the design of the ad-libitum buffet. The pre-defined and selection of foods allowed for a covert examination of food choice between healthy and unhealthy foods and drinks matched for energy density, as well as including both high and low energy dense foods. Study limitations include only having a cross-sectional analysis of behaviour and consumption, and the inclusion of only the DEBQ as a self-report measure of eating behaviours. However, given that restrained and disinhibited/external eating measures, such as the DEBQ and TFEQ have been shown to be correlated among weight groups (Bohrer et al., 2015), the results are predicted to be the same having used the TFEQ. Given the importance of restrained eating behaviour in energy intake, including unhealthy food choice, it would be interesting to investigate whether eating behaviours, such as restraint and disinhibition/external eating are able to improve in a more real-world setting. Future work should investigate whether baseline eating behaviours are predictive of weight loss and weight maintenance during a weight loss intervention. Furthermore, it would also be interesting to investigate whether eating behaviours can change during periods of weight loss and weight maintenance and if these changes are associated with weight change.

The results presented in this chapter provide evidence that low restraint may be associated with higher energy intake of food and may be associated with unhealthy food choice, but restraint does not seem to be related to desire for healthy food choices. Furthermore, restraint was also shown to be negatively associated with both high and low energy density food consumption and so further work is required to understand this relationship. Therefore, the results suggest that restraint is an important factor when making unhealthy (but not healthy) food choices as well as overall energy intake. Consequently, future work should investigate the extent to which eating behaviours, such as restraint and disinhibition, change during periods of weight loss and whether these eating behaviours can predict weight loss during a weight loss programme as well as weight change during a subsequent weight maintenance period.

CHAPTER 3

THE RELATIONSHIP BETWEEN EATING BEHAVIOURS AND WEIGHT CHANGE²

Whilst the previous chapter demonstrated that restraint was associated with energy intake, evidence from the literature also suggests that eating behaviours are also associated with weight change during and following weight loss interventions. However, it is unclear whether these measures influence weight change resulting from a low-calorie diet in a number of different countries. I used data from the multinational Diet, Obesity and Genes (“DiOGenes”) study to investigate the relationship between baseline scores and changes in eating behaviour measures and changes in weight during weight loss and weight maintenance. The study included 555 participants from 8 centres across Europe. Eating behaviour and weight measurements were collected on three occasions at baseline, post 8-week weight loss programme and after 6-months of weight maintenance.

The results of this chapter suggest that lower baseline restraint, but not disinhibition or hunger, is associated with greater weight loss during the 8-week low-energy-diet. In addition, this chapter also shows that greater weight regain during the weight

² Davies KM, Ahern AL, Solis-Trapala I, Westenhoefer J, Stubbs J, Lawton C, Whybrow S, Blundell J, Raats M and Jebb SA, on behalf of the DiOGenes consortium. *Dietary restraint and disinhibition are associated with weight loss and weight maintenance*. Obesity (in press)

maintenance phase was associated with increases in disinhibition and decreases in restraint, but not changes in hunger. Therefore, interventions which increase restraint and reduce disinhibition may be useful behavioural strategies to achieve longer term weight maintenance.

3.1 Introduction

The prevalence of obesity varies markedly from country to country. For example, a recent worldwide systematic analysis of obesity prevalence has shown that within Western Europe (including countries such as Germany, Spain, Italy, France, UK, Greece, Netherlands) the proportion of men who were overweight was 61.3% (range 34.4-74.0%) and women who are overweight was on average 47.6% (range 36.1-60.9%). The proportion of men who were obese was 20.5% (range 10.6-29.0%) and proportion of women was 21.0% (7.2-28.9%) (Ng et al., 2014). Andorra had the lowest proportion of overweight and obese men and women, whereas Malta recorded the highest percentage of men who were overweight or obese and Iceland had the highest percentage of women who were overweight or obese. The Central Europe group (including countries such as Bulgaria, Hungary, Romania, Poland) had similar results the proportion of men who were overweight was 62.2% (range 56.2-65.6%) and women who were overweight was 50.4% (range 45.8-54.8%). In addition, men who were obese was on average 18.0% (range 9.2-21.7%) and women who were obese was on average 20.7% (range: 11.1-24.7%). Albania recorded the lowest proportions for both men and women, whereas Hungary recorded the highest proportions of overweight and obesity for men and women in Central Europe. In the Eastern Europe group (including countries such as Estonia, Belarus, Russia, Lithuania) the proportion of men who were overweight

was 55.0% (range 44.1-63.9%) and women who were overweight was 57.8% (range 44.7-58.9%). In addition, men who were obese was on average 14.8% (range 8.8-19.0%) and women who were obese was on average 27.0% (range: 14.2-28.8%). Belarus reported the lowest proportion of men and women who were overweight or obese. Lithuania recorded the highest proportion of men who were overweight and Estonia has the highest percentage of men who were obese. Whereas, for women, Russia has the highest proportion of women who were overweight and Moldova had the highest percentage of women who were obese (Ng et al., 2014). Therefore, these results show there is a large range in the percentage of individuals who are overweight or who have obesity across Europe. As mentioned in Chapter 1, while a number of behavioural and lifestyle interventions have been shown to help overweight and obese individuals to control their weight (Hartmann-Boyce et al., 2014), there is considerable heterogeneity in the outcomes observed. Some individuals find it difficult to adhere to these interventions and consequently, often do not lose weight, even when participating in intensive weight loss programmes (Brownell, 2010). Furthermore, many individuals who are able to lose weight initially, find it difficult to maintain this weight loss (Jeffery et al., 2000) or avoid future weight gain (Stice et al., 2006).

The individual variation in eating behaviour measures, such as dietary restraint, disinhibition and hunger, may help explain some of this inter-individual variability during weight loss interventions and subsequent weight-loss maintenance (French et al., 2012, Berthoud, 2011). The relationship between measures of these eating behaviour measures and weight change during short- and long-term weight loss has been studied in a variety of settings. Overall, studies have shown that higher baseline measures of hunger and disinhibition (and low restraint scores) are able to predict greater weight

loss during behavioural weight loss programmes (Batra et al., 2013, Bryant et al., 2012, McGuire et al., 2001, Foster et al., 1998). While behavioural interventions and hypo-energetic diets can achieve modest weight loss, very low-calorie-diets can achieve even greater weight loss (Parretti et al., 2016). Studies which have used very-low calorie diet programmes with or without behavioural therapy, have mostly found no association between baseline eating behaviour measures and changes in weight during the intervention (Vogels et al., 2005, Vogels and Westerterp-Plantenga, 2007, Westerterp-Plantenga et al., 1998, Pekkarinen et al., 1996, Clark et al., 1994, LaPorte and Stunkard, 1990). However, one study found a modest relationship between low baseline restraint scores and greater weight loss during a very low-calorie diet with behavioural counselling intervention (Foster et al., 1998).

Studies have also investigated the relationship between changes in eating behaviour measures and changes in weight during a variety of interventions. Decreases in disinhibition and hunger and increases in restraint have been shown to be associated with weight loss during behavioural (Batra et al., 2013, Keranen et al., 2009, Teixeira et al., 2010, McGuire et al., 2001, Bryant et al., 2012) and combined behavioural and very low-calorie diet weight loss programmes (Pekkarinen et al., 1996, Foster et al., 1998). Furthermore, changes in eating behaviour measures during weight loss programmes have also been shown to be associated with weight change during a period of weight maintenance. For example, studies have shown that increases in dietary restraint during a very low-calorie diet were associated with less regain in weight during a 1-year follow-up period (Vogels et al., 2005, Westerterp-Plantenga et al., 1998) and decreases in disinhibition during a 3 month weight loss programme predicted more success in maintaining weight loss during a further 3 months of weight maintenance (Butryn et al.,

2009). Data from the Maastricht Weight Maintenance Study have also shown that changes in eating behaviour is associated with changes in weight during weight maintenance, for example, greater increases in dietary restraint were found to be associated with less weight regain over 2 years following a very low-calorie diet (Vogels and Westerterp-Plantenga, 2007).

As discussed, previous studies have been able to show that both baseline scores and changes in eating behaviour scores are associated with weight change during weight loss programmes and weight maintenance. However, there is no research to my knowledge which has investigated this relationship across countries. One study, the Diet, Obesity and Genes “DiOGenes” study, is unique in that it was conducted across eight European countries (Netherlands, Denmark, UK, Greece, Germany, Spain, Bulgaria and Czech Republic) and therefore allowed me to investigate the relationships between eating behaviours and weight change on a multi-national level, across eight European countries.

3.2 Aim and Hypotheses

Aims	Hypotheses
Primary	
The overarching aim was to explore whether baseline or changes in eating behaviour measures were associated with changes in weight during weight loss and weight maintenance across eight European countries.	I predicted that the same relationship would be seen across all countries and that there will be no interaction with country.

Specific aims	Specific hypotheses
To investigate the relationship between baseline eating behaviour scores and weight change during the 8-week low-calorie diet.	I predicted that lower baseline restraint (but not disinhibition or hunger) would be associated with greater weight loss during the 8-week low-calorie diet.
To examine the relationship between post-low-calorie diet (Visit 2) eating behaviour scores and weight change during the weight maintenance period.	I predicted that higher restraint and lower disinhibition and hunger scores after the low-calorie diet would predict less weight re-gain during the 6-month weight maintenance period.
To study the relationship between changes in eating behaviour scores and changes in weight during the 8-week low-calorie diet.	I predicted that increases in restraint and decreases in disinhibition (but not hunger) would be associated with greater decreases in weight during the 8-week low-calorie diet.
To investigate the relationship between changes in eating behaviour scores and changes in weight during the 6-month weight maintenance period.	I predicted that increases in restraint and decreases in disinhibition (but not hunger) would be associated with less weight regain during the 6-month weight maintenance period.
To examine the relationship between changes in eating behaviour scores during the 8-week low-calorie diet and changes in weight during the 6-month weight maintenance period.	I predicted that increases in restraint and decreases in disinhibition during the 8-week low-calorie diet would be associated with less weight regain during the weight maintenance period.

3.3 Methods

Study Participants

Adults aged between 18 and 65 years old were screened and recruited for the study if they were part of a family including at least 1 healthy but overweight adult, and at least 1 healthy child aged 5 to 18 years and who were willing to participate in study investigations. The study was approved by local ethics committees in each country. All study participants signed an informed consent form after being given verbal and written details of the study, but before taking part in any study activities.

Study Design

The data from this study was collected during the DiOGenes study where the full methods and procedures have been previously described in the literature (Larsen et al., 2010a, Larsen et al., 2010b). For the purpose of my thesis I will describe how the data I analysed was collected during the study. In brief, the study was carried out by 8 centres in Europe (Netherlands, Denmark, United Kingdom, Greece, Germany, Spain, Bulgaria and Czech Republic). Eligible adult participants who enrolled in the study initially underwent an initial baseline measurement day (Visit 1) before completing an 8-week weight-loss programme with a low-calorie diet (LCD). This was followed by a follow-up visit (Visit 2) and subsequently being randomised to a dietary intervention (see further details below) during a 6-month weight maintenance period with a follow up visit after this period (Visit 3). There was another follow up after 6-months of free-living with no dietary instruction at the 12-months post weight-loss programme time point. However, this 12-month visit did not include collecting any behavioural data and was therefore not included in this analysis (Larsen et al., 2010a).

Low Calorie Diet

A low-calorie diet in the form of a liquid formula diet (Modifast®, Nutrition et Santé, Belgium) was provided to participants for 8-weeks during the weight-loss programme. The diet provided 800-1000kcal/day (3.4–4.2 MJ d⁻¹) and participants could eat an additional 200g of vegetables per day.

Dietary Intervention

Following the 8-week low-calorie diet, overweight or individuals with obesity within families where at least 1 individual lost at least 8% of his or her initial body weight were cluster randomized to 1 of 5 diets. These diets consisted of either a low/high protein or low/high glycaemic index (GI), with the five diets being low protein/low GI; high protein/low GI; low protein/ high GI; high protein/ high GI and control of medium protein with no GI instruction). These diets were stratified according to centre, number of eligible adults and adults with BMI >34 kg/m². Participants were scheduled to receive dietary counselling every 2-4 weeks during the weight maintenance period and provided with recipes and behavioural advice to encourage adherence. Participants were instructed to maintain their new weight (i.e. their weight loss) during this period, but further weight loss was allowed.

Measures and Questionnaires

Body weight

Participants attended clinical investigation days before the low-calorie diet (Visit 1), post low-calorie diet (Visit 2) and at the end of the weight maintenance phase (Visit 3). Body weight and eating behaviours were measured at all visits. Body weight was measured, to the nearest 0.1kg, in the morning in subjects in a fasted state, wearing underwear only and having emptied their bladder.

The Three Factor Eating Questionnaire (TFEQ)

The TFEQ (Stunkard and Messick, 1985) is a 51-item, self-report instrument with three factors, assessing dietary restraint, disinhibition and hunger. The restraint subscale (range 0-21) assesses the degree of cognitive effort one exerts over eating behaviours. The disinhibition subscale (range 0-16) measures susceptibility to loss of control over eating. The hunger subscale (range 0-14) measures subjective feeling of hunger. The TFEQ has well-established psychometric properties (Bond et al., 2001) and has been used in a variety of weight control interventions; higher scores represent higher levels on all subscales. The questionnaire can be found in Appendix 3.

Statistical Analysis

Comparison of baseline differences of weight and eating behaviours between gender, age, centre and randomised diet group were made using either Student's T test or one-way ANOVA corrected for multiple comparisons, as appropriate.

Linear regression models were fitted to weight change during the 8-week low-calorie diet and 6-month weight maintenance period, respectively, to investigate the association between baseline (Visit 1) or post low-calorie diet (Visit 2) eating behaviour measures and weight change; and the relationship between changes in eating behaviours and changes in weight in completers of the study. To focus on eating behaviours as predictors of weight change beyond the contribution attributable to gender, age and weight at baseline/ weight at visit 2 (post- low-calorie diet), these variables were adjusted for in all the regression models. Additionally, centre (and randomised diet group during weight maintenance) covariates were also included to adjust for centre and diet group variability. Further analysis was performed by adding an interaction term for disinhibition and restraint for each of the models. An interaction

for gender, centre and each of the eating behaviour measures was also assessed. Analyses were performed using the R statistical programme (R, 2008) (Version 3.0.2, R).

3.4 Results

Participant demographics

Of the 938 eligible individuals who were weighed at baseline, 555 (59% of the 938) participants completed the study (Figure 3.1). Of these, 102 participants (18%) were from the Netherlands; 104 (19%) from Denmark; 53 (10%) from the UK; 35 (6%) from Greece; 68 (12%) from Germany; 54 (10%) from Spain; 72 (13%) from Bulgaria and 67 (12%) from the Czech Republic. Of these participants, the majority were Caucasian (545 individuals 98.2%).

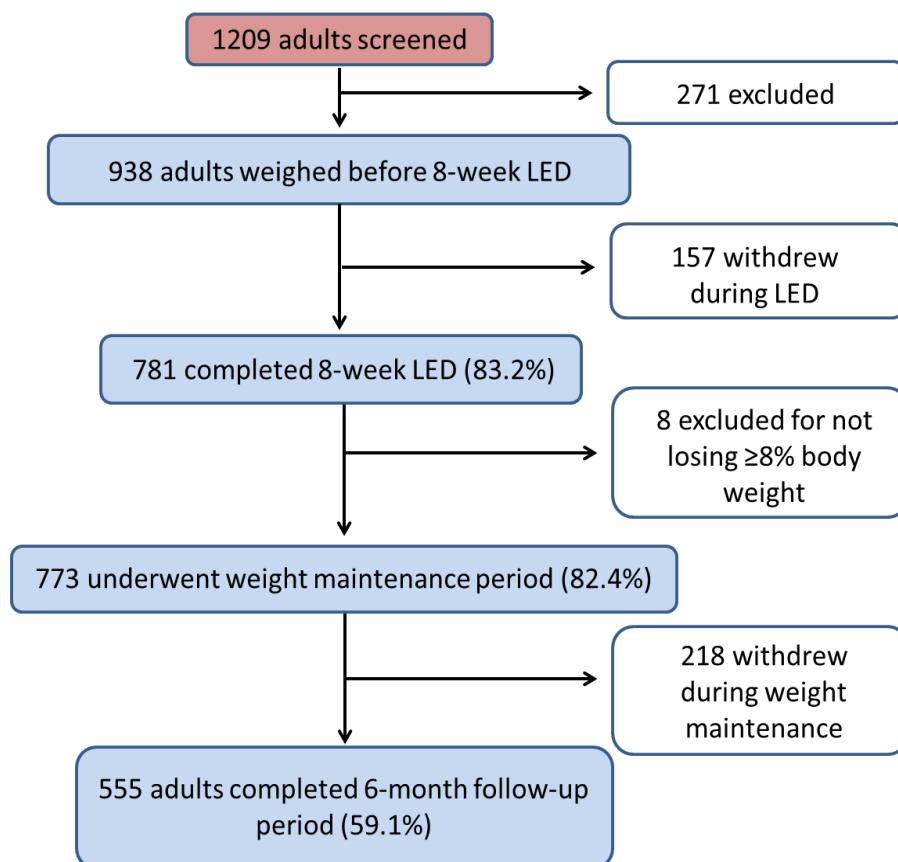


Figure 3.1: Flow diagram to show the number of participants at each stage of the study

Participants comprised 189 (34%) males and 366 (66%) females with an age range of 24-63 years (mean $42.28 \pm \text{SD } 6.12$). Their BMI ranged from 25.64 to 49.96 (mean $34.25 \pm \text{SD } 4.87$) and weight ranged from 62.4kg to 165.0kg (mean $99.39 \pm \text{SD } 17.35$). At baseline, women on average had significantly greater disinhibition scores and significantly greater restraint scores than men (Table 3.1). Further details about the participant demographics can be found published in Larsen et al, 2010 (Larsen et al., 2010b).

Changes in weight and eating behaviours between men and women

Mean weight change for all participants during the 8-week low-calorie diet was -11.14kg (11.43%) and 0.50kg (0.33%) during the weight maintenance period. On average, men lost more weight during the 8-week low-calorie diet ($-12.89 \pm 3.89\text{kg}$, 14.35%) than women ($-10.23\text{kg} \pm 2.87\text{kg}$, 9.93%) see Table 1 ($p < .001$). During the weight maintenance period, men on average gained a small amount of weight ($1.57 \pm 5.32\text{kg}$, 1.42%), while women remained stable ($-0.06 \pm 5.48\text{kg}$, 0.24%), see Table 1 ($p = .001$). There were no significant differences in changes in disinhibition, restraint or hunger during the 8-week low-calorie diet and 6-month weight maintenance period between men and women (Table 3.1).

Country differences in weight and eating behaviours

As previously reported (Larsen et al., 2010a), there were significant differences between countries (centres) in baseline weight, as shown in Table 3.2. There were also significant differences in baseline TFEQ scores between countries (Table 3.2).

There was a significant difference between centres in changes in disinhibition, restraint and hunger scores during the low-calorie diet period and changes in restraint score during the weight maintenance period. However, average disinhibition and hunger

scores for each country all decreased during the low-calorie diet and the average scores for restraint for each country increased during the low-calorie diet and continued to increase during the weight maintenance period (Table 3.2). There were no differences between centres in changes in hunger during the low-calorie diet period nor were there any significant differences in changes in hunger or disinhibition scores during the weight maintenance period. These differences have been controlled for in the regression analysis.

Table 3.1: Baseline measures and changes in weight, disinhibition, and restraint for men, women and all participants

	Weight (kg)			Disinhibition score (0-16)			Restraint score (0-21)			Hunger score (0-14)		
	Baseline	$\Delta 1-2$	$\Delta 2-3$	Baseline	$\Delta 1-2$	$\Delta 2-3$	Baseline	$\Delta 1-2$	$\Delta 2-3$	Baseline	$\Delta 1-2$	$\Delta 2-3$
Average for all (SD)	99.39 (17.65)	-11.14 (3.48)	0.50 (5.48)	9.03 (3.53)	-0.84 (2.54)	-0.45 (2.65)	8.09 (4.24)	3.27 (4.10)	1.34 (3.89)	7.24 (3.50)	-0.91 (2.88)	-0.68 (2.70)
Men average (SD)	108.64 (17.80)	-12.89 (3.89)	1.57 (5.32)	7.89 (3.28)	-0.52 (2.36)	-0.29 (2.53)	6.05 (3.55)	3.73 (4.25)	1.51 (4.39)	7.35 (3.48)	-1.03 (2.93)	-0.65 (2.58)
Women average (SD)	94.60 (15.57)	-10.23 (2.87)	-0.06 (5.48)	9.62 (3.52)	-1.01 (2.62)	-0.53 (2.71)	9.16 (4.18)	3.02 (4.01)	1.24 (3.60)	7.18 (3.51)	-0.84 (2.86)	-0.70 (2.76)
Actual difference between gender (SE)	14.04 (1.53)	2.65 (0.32)	1.62 (0.48)	1.73 (0.30)	0.49 (0.22)	0.24 (0.23)	3.12 (0.34)	0.71 (0.37)	0.27 (0.37)	0.17 (0.31)	0.19 (0.26)	0.05 (0.24)
P-value (Between gender)	<.001	<.001	.001	<.001	.085	.237	<.001	.056	.303	.596	.476	.844

$\Delta 1-2$ =Change during 8-week low-calorie diet; $\Delta 2-3$ =Change during 6-month weight maintenance period

NB: Negative values correspond to a decrease and positive values correspond to an increase in the outcome variable.

Table 3.2: Mean (SD) baseline measures and changes in weight, disinhibition, and restraint between countries (centres)												
	Weight (kg)			Disinhibition score (0-16)			Restraint score (0-21)			Hunger score (0-14)		
	Baseline	Δ1-2	Δ2-3	Baseline	Δ1-2	Δ2-3	Baseline	Δ1-2	Δ2-3	Baseline	Δ1-2	Δ2-3
Netherlands (n=102)	96.47 (14.7)	-11.11 (3.38)	2.05 (5.07)	8.34 (3.35)	-1.00 (2.45)	-0.26 (2.65)	7.07 (3.78)	4.33 (4.05)	1.36 (3.75)	6.67 (3.58)	-1.30 (2.81)	-0.32 (2.75)
Denmark (n=104)	102.90 (16.79)	-10.96 (3.43)	1.04 (4.14)	8.71 (3.30)	-0.22 (2.29)	-0.92 (2.40)	7.44 (3.97)	2.09 (3.26)	2.62 (3.86)	6.73 (3.59)	-0.20 (2.50)	-1.01 (2.70)
UK (n=53)	95.38 (17.98)	-11.34 (3.54)	2.55 (5.14)	10.63 (3.11)	-0.58 (1.97)	-0.60 (2.97)	7.46 (3.61)	2.12 (2.99)	2.29 (4.53)	8.04 (3.33)	-0.02 (2.25)	-1.48 (3.53)
Greece (n=35)	99.50 (18.01)	-12.95 (4.95)	-0.37 (5.99)	10.00 (3.27)	-1.83 (3.09)	-0.36 (3.13)	8.06 (4.12)	4.83 (5.52)	1.21 (5.35)	8.26 (2.75)	-1.80 (3.24)	-0.58 (2.99)
Germany (n=68)	99.09 (14.54)	-11.19 (3.28)	2.13 (5.01)	7.44 (3.21)	-0.69 (1.93)	0.00 (2.42)	8.41 (4.87)	3.66 (3.63)	0.16 (3.46)	6.01 (2.99)	-0.93 (2.62)	-0.75 (2.31)
Spain (n=54)	94.09 (16.45)	-9.21 (2.66)	-0.60 (4.44)	9.02 (3.64)	-1.24 (2.57)	-0.16 (2.12)	9.13 (4.20)	3.18 (3.40)	1.43 (3.38)	7.25 (3.45)	-1.55 (3.05)	-0.10 (2.35)
Bulgaria (n=72)	105.67 (22.49)	-11.57 (3.12)	-4.63 (6.09)	9.83 (3.92)	-0.29 (3.10)	-0.58 (2.59)	9.61 (5.08)	2.14 (5.46)	0.71 (3.23)	8.10 (3.67)	-0.47 (3.28)	-0.72 (2.62)
Czech Republic (n=67)	99.30 (18.30)	-11.37 (3.39)	0.86 (4.96)	9.55 (3.58)	-1.69 (2.61)	-0.50 (3.07)	8.36 (3.59)	4.38 (3.45)	0.48 (3.60)	8.09 (3.48)	-1.53 (3.08)	-0.48 (2.28)
P-value (Between countries)	.001	>.001	>.001	>.001	.001	.474	.002	>.001	.001	.004	.18	.515
Δ 1-2=Change during 8-week low-calorie diet; Δ 2-3 =Change during 6-month weight maintenance period.												
NB: Negative values correspond to a decrease and positive values correspond to an increase in the outcome variable.												

Baseline measures of eating behaviour as predictors of weight change

In a model containing changes in weight during the low-calorie diet as the dependent variable and baseline eating behaviour scores as independent variables, baseline restraint was positively associated ($R^2 = 0.40$, $p = 0.003$) with change in weight during the low-calorie diet after being adjusted for age, gender, centre and baseline weight, see Table 4. Lower baseline restraint scores were associated with greater decreases in weight during the low-calorie diet (Figure 3.2). A one standard deviation lower baseline restraint score was associated with a 0.37kg greater weight loss.

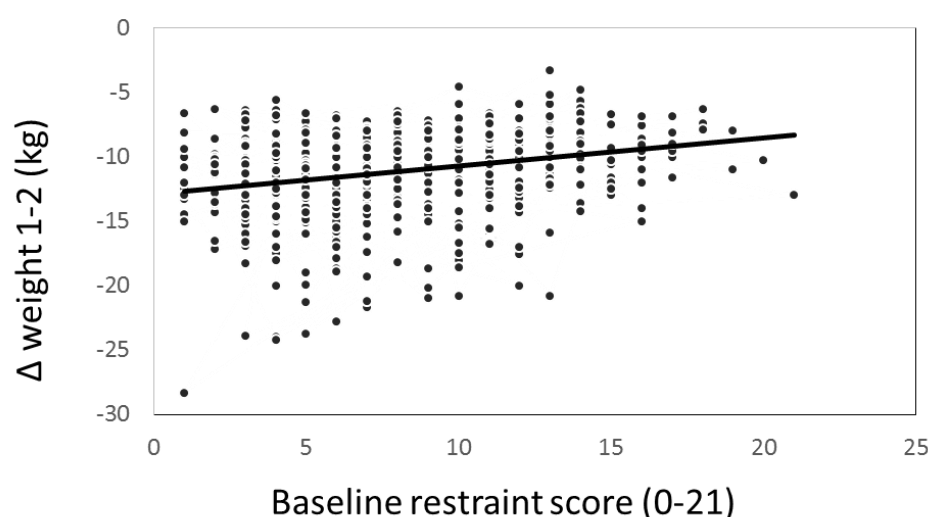


Figure 3.2: Scatter plot for the relationship between baseline restraint and changes in weight during the 8-week low-calorie diet

There were no significant associations between baseline disinhibition or hunger and change in weight during the low-calorie diet. There were no significant associations between post- low-calorie diet (Visit 2) disinhibition, hunger and restraint scores and change in weight during the 6-month weight maintenance period (Table 3.3). There was

no interaction between baseline disinhibition and restraint scores nor was there an interaction between gender or centre and any of the baseline scores of eating behaviour measures.

Table 3.3: Regression models for baseline and post- low-calorie diet (LCD) disinhibition and restraint scores as predictors of weight change

Outcome variable	Predictor variable	Basic model				Adjusted model [†]			
		R ²	β (SE)	T-value	P-value	R ²	β (SE)	T-value	P-value
Δ 1-2 Weight	Baseline disinhibition	0.07	0.029 (0.05)	0.552	.581	0.40	- 0.047 (0.05)	- 1.017	.310
	Baseline restraint		0.214 (0.04)	6.074	<.001		0.088 (0.03)	3.151	.003
	Baseline hunger		-0.026 (0.06)	- 0.464	.643		0.055 (0.05)	1.188	.235
Δ 2-3 Weight	Post-LCD disinhibition	0.002	-0.076 (0.10)	- 0.783	.434	0.10	0.014 (0.10)	0.145	.885
	Post-LCD restraint		-0.028 (0.06)	- 0.503	.615		0.082 (0.06)	1.466	.143
	Post-LCD hunger		0.054 (0.10)	0.558	.577		0.089 (0.10)	0.949	.343

Δ 1-2=Change during 8-week low-calorie liquid diet; Δ 2-3 =Change during 6-month weight maintenance period

[†]Adjusted model was controlled for age, gender, centre, weight maintenance diet (for models with changes between 2-3 only) and weight at baseline for Δ 1-2 and weight at post- low-calorie diet for Δ 2-3

Association between changes in eating behaviour measures and changes in weight
In a linear regression model containing changes in weight as the dependent variable and changes in disinhibition, restraint and hunger scores as independent variables, there was a significant negative association between change in restraint score and change in

weight during the low-calorie diet ($R^2=0.12$, $p=0.014$). Greater increases in restraint were associated with greater decreases in weight. However, when this model was adjusted for age, gender, centre and baseline weight there was no longer a significant negative association between change in restraint and change in weight ($R^2=0.39$, $p=0.231$) (Table 3.4). There was no significant association between change in disinhibition or hunger and weight change during the low-calorie diet.

Change in disinhibition and change in restraint during the weight maintenance period were significantly associated with change in weight during the weight maintenance period ($R^2=0.16$) after being adjusted for age, gender, centre, weight maintenance diet and post- low-calorie diet weight, see Table 3.4. Change in disinhibition was positively associated ($\beta=0.261$, $p=0.007$) with change in weight during the weight maintenance period, i.e. greater decreases in disinhibition were associated with greater less weight regain, as shown in the partial regression plot in Figure 3.3a. A one standard deviation greater decrease in disinhibition was associated with a 0.69kg greater decrease in weight during the weight maintenance period. Change in restraint was negatively associated ($\beta=-0.245$, $p=0.001$) with change in weight, i.e. greater increases in restraint were associated with less weight regain during the weight maintenance period (Figure 3.3b). A one standard deviation greater increase in restraint was associated with a 0.95kg greater decrease in weight during the weight maintenance period. There was no significant association between change in hunger and change in weight during the 6-month weight maintenance period.

There were no significant associations between changes in any of the eating behaviour measures during the 8-week low-calorie diet and changes in weight during the weight

maintenance period. There was no significant interaction between changes in disinhibition and restraint during the low-calorie diet or weight maintenance period. No significant interaction was seen between gender or country (centre) and changes in disinhibition, restraint or hunger during the low-calorie diet or weight maintenance period.

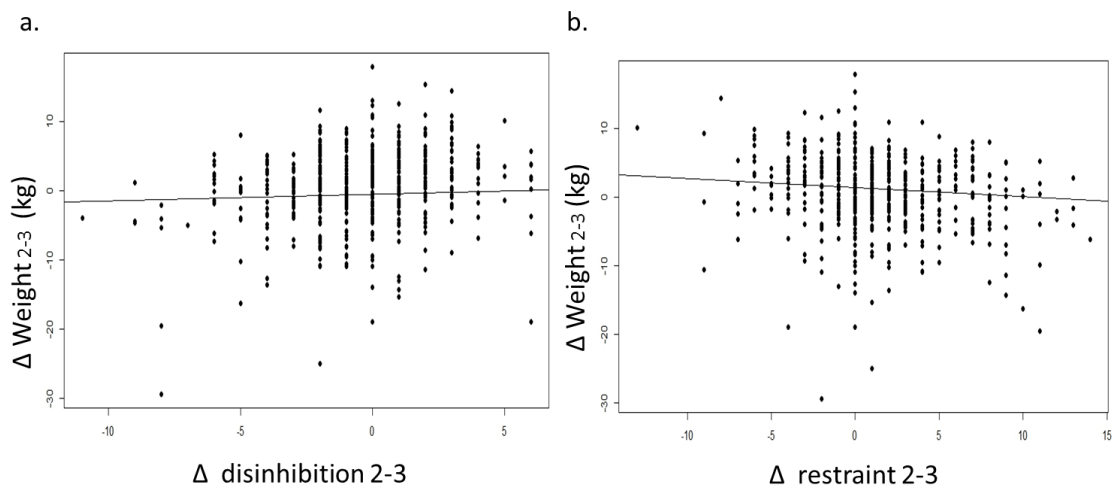


Figure 3.3: Scatter plots for changes in weight with changes in a) disinhibition and b) restraint during the 6-month weight maintenance period

Table 3.4: Regression models for the association between changes in disinhibition and restraint scores with changes in weight

Outcome variable	Predictor variable	Basic model				Adjusted model [†]			
		R ²	β (SE)	T-value	P-value	R ²	β (SE)	T-value	P-value
Δ 1-2 Weight	Δ 1-2 Disinhibition	0.12	-0.068 (0.07)	-0.979	.328	0.39	0.021 (0.06)	0.371	.711
	Δ 1-2 Restraint		-0.101 (0.04)	-2.470	.014*		-0.039 (0.03)	-1.199	.231
	Δ 1-2 Hunger		0.004 (0.06)	0.070	.944		-0.021 (0.05)	-0.428	.669
Δ 2-3 Weight	Δ 1-2 Disinhibition	0.001	0.038 (0.11)	0.348	.728	0.09	-0.027 (0.11)	-0.253	.800
	Δ 1-2 Restraint		0.030 (0.10)	0.468	.640		0.007 (0.06)	0.115	.908
	Δ 1-2 Hunger		0.054 (0.10)	0.557	.578		0.057 (0.09)	0.616	.538
	Δ 2-3 Disinhibition	0.06	0.311 (0.10)	3.065	.002	0.16	0.261 (0.10)	2.694	.007
	Δ 2-3 Restraint		-0.172 (0.07)	-2.610	.009		-0.245 (0.06)	-3.879	.001
	Δ 2-3 Hunger		0.0689 (0.10)	0.688	.492		0.056 (0.10)	0.582	.561

Δ 1-2=Change during 8-week low-calorie liquid diet; Δ 2-3 =Change during 6-month weight maintenance period

[†]Adjusted model was controlled for age, gender, centre, weight maintenance diet (for models with changes between 2-3 only) and weight at baseline for changes between 1-2 and weight at post- low-calorie diet for changes between 2-3

3.5 Discussion

The primary aim of this study was to investigate whether both baseline scores and/or changes in eating behaviour measures were associated with changes in weight during weight loss and weight maintenance. I will discuss the baseline results first and then

move on to discuss the changes in eating behaviours and weight. My results found that lower baseline dietary restraint scores were associated with greater weight loss during an 8-week low-calorie diet. This was consistent with one other study which used a very-low energy diet and showed that individuals with lower restraint scores prior to 5-6 months of treatment lost 3kg more than those with higher restraint scores (Foster et al., 1998). In contrast, behavioural weight loss intervention studies (Batra et al., 2013, Bryant et al., 2012, McGuire et al., 2001) have shown that higher baseline measures of hunger and disinhibition (but not restraint) are able to predict greater weight loss during the intervention. In addition, most studies using liquid diets have shown no association between baseline dietary restraint, disinhibition and hunger with weight loss (Vogels et al., 2005, Vogels and Westerterp-Plantenga, 2007, Westerterp-Plantenga et al., 1998, Pekkarinen et al., 1996, Clark et al., 1994, LaPorte and Stunkard, 1990). This result of my study could be partially explained by the association of restraint and baseline weight. Individuals who have higher restraint scores have been shown to have lower baseline body weight, suggesting that low restraint could be a proxy for higher body weight at baseline (Foster et al., 1998). Indeed, individuals who had lower baseline restraint scores had higher baseline body weight ($t(df=544)=-4.60$, $p<.001$). Also consistent with the very-low energy diet study (Foster et al., 1998), but not most behavioural weight management studies (Batra et al., 2013, Bryant et al., 2012), I found that baseline disinhibition and hunger were not associated with weight loss during the low-calorie diet. This may reflect an important difference between liquid diets and food-based behavioural interventions; the latter requiring subjects to exert greater control over the selection of food in behavioural programmes. It is plausible that liquid diets may be particularly effective, relative to standard behavioural interventions, for participants

with low dietary restraint. However, future studies would need to explore this experimentally.

An interaction between disinhibition and restraint has been reported previously such that those with higher disinhibition and lower restraint have a greater susceptibility to weight gain over time (Bryant et al., 2010). My analysis saw no significant interactions between baseline measures of disinhibition and restraint or changes in disinhibition and restraint with weight change during the weight maintenance period. Consistent with previous studies, women in this study had significantly greater disinhibition and restraint scores than men (Provencher et al., 2003). However, there was no interaction of gender or country with any of the eating behaviour measures in any of the regression models.

My analysis also revealed that increases in disinhibition and decreases in restraint are associated with increases in weight, during a weight maintenance period following a period of acute weight loss, using a low-calorie diet, which persist across European countries. However, these effect sizes were relatively small and these models explain only a small proportion of the variance in weight outcomes. The observed association between decreases in restraint and increases in weight during weight maintenance supports previous studies of weight maintenance following a very low-calorie diet with a behavioural weight management programme (Vogels and Westerterp-Plantenga, 2007). This is also consistent with findings from the National Weight Control Registry, where individuals on a liquid formula diet reported higher dietary restraint in order to maintain their weight loss (McGuire et al., 1998). This analysis also further confirms the lack of association with self-reported hunger (Vogels and Westerterp-Plantenga, 2007).

In contrast to studies which have shown associations between changes in eating behaviour measures and weight change during very-low energy diet and behavioural weight loss programmes (Batra et al., 2013, Bryant et al., 2012, Teixeira et al., 2010, McGuire et al., 2001, Pekkarinen et al., 1996, Foster et al., 1998, Keranen et al., 2009), I found no associations between changes in eating behaviour measures and weight change during the 8-week low-calorie diet. Increases in restraint during a very-low energy diet have previously been shown to be associated with subsequent weight loss during a 1-year period of weight maintenance (Vogels et al., 2005, Westerterp-Plantenga et al., 1998) and greater decreases in disinhibition during a 3-month low calorie diet predicted greater increases in weight during a further 3-month weight maintenance period. However, my results show no similar associations in this study between changes in restraint or disinhibition during the low-calorie diet with changes in weight during the weight maintenance period. These results may be due to measures of restraint, disinhibition and perceived hunger during the low-calorie diet may primarily relate to compliance with a tightly prescribed treatment, whereas in the weight maintenance period individuals would have greater capacity to relate to their control of eating behaviour.

The limitations of this study include that the study only had a 6-month follow-up which confines the analysis of the long-term relationship between changes in eating behaviours and weight maintenance, but early changes are usually a good predictor of longer term success (Vogels et al., 2005, Westerterp-Plantenga et al., 1998). There was substantial loss to follow up during the study. At the end of the 6-month weight maintenance period there were 375 individuals lost to follow-up and 8 excluded during the study, leaving only 59% of the original 938 individuals who started the study. This

study may also have limited heterogeneity because only participants from a family where one member lost at least 8% of their original body weight were retained in the study, subsequently reducing the variation in weight loss across the population studied.

In conclusion, my analysis in this chapter indicates that an increase in disinhibition and decrease in restraint are associated with an increase in weight during a 6-month weight maintenance period following an 8-week low-energy liquid diet. Interventions for weight-loss maintenance may be enhanced by strategies which decrease disinhibition and facilitate effective dietary restraint. Lower restraint (but not disinhibition or hunger) at baseline predicted greater weight loss during the 8-week low energy diet, suggesting that people with low dietary restraint appear to benefit from weight loss on liquid formula diets. While these results are important to understand the relation between eating behaviours and weight control, understanding the underlying cognitive and motivational factors that contribute to these individual differences is also important.

CHAPTER 4

THE RELATIONSHIP BETWEEN EATING BEHAVIOURS, COGNITION AND MOTIVATION

As previously shown in Chapters 1 and 2, individual differences in eating behaviours are known to be associated with food intake, weight control and obesity. However, understanding the underlying cognitive and motivational factors that contribute to these individual differences is important. In this study, I recruited both lean and overweight, male and female participants who attended two sessions (one in a fasted state and one in a fed state) to investigate the degree to which motivational (fasted-status and hedonic hunger) and cognitive (impulsivity and memory) factors could predict eating behaviours. I also explored the extent to which variance in BMI was predicted by eating behaviours, cognitive and motivational factors and I aimed to replicate previous data suggesting that BMI is negatively associated with episodic memory.

I found that restraint, hunger and episodic memory were associated with TFEQ disinhibition and those with higher hedonic hunger (PFS total score) have greater levels of TFEQ measured levels of hunger. Given these results and that the study population did not include dieters, further work should investigate whether dieting influences cognitive and motivational factors in both lean and overweight individuals. This study also extended previous findings that BMI is negatively associated with episodic memory,

but adds the novel insight that current hunger status has no influence on this association. Further work should investigate whether this relationship is also seen in episodic memory for non-food images within the THT task. In conclusion, cognitive (impulsivity but not memory) and motivational factors (hedonic hunger but not fasting status) are important in explaining the variance in disinhibited eating behaviour.

4.1 Introduction

While the previous chapters have shown that identifying an individual's eating behaviour profile is a key factor in understanding overeating and obesity, these behaviours are very descriptive indices of how an individual tends to act around food. Mounting evidence suggests that several psychological factors contribute to the regulation of consumption. The decision to eat a given food at a given time is made in accordance with relative hunger and satiety, which is controlled not only by physiological homeostatic signals, but also by a psychological assessment of what has recently been eaten, and what eating opportunities may occur in the near future (Robinson et al., 2013b, Wansink and van Ittersum, 2007). The resulting consumption behaviour will be further influenced by an individual's inherent ability to inhibit any pre-potent tendency to consume the available food regardless of current need state (Nederkoorn et al., 2009, Guerrieri et al., 2007, Rollins et al., 2010, Appelhans et al., 2011). It is therefore important when investigating factors contributing to obesity to consider not only individual differences in eating behaviours themselves, but also the cognitive and psychological factors that may contribute to these individual differences, and the extent to which they are predictive of overeating and weight gain.

A number of studies of eating behaviour have examined factors such as disinhibition and cognitive restraint. The main instrument used to measure these behaviours is the Three Factor Eating Questionnaire (TFEQ) (Stunkard and Messick, 1985). The disinhibition-subscale measures the tendency to overeat in response to external food cues or emotional states, while the restraint-subscale measures the conscious restriction of food intake to prevent weight gain or to promote weight loss. These measures of disinhibition and restraint have not only been shown to be associated with BMI, e.g. (Chaput et al., 2009, Gallant et al., 2010, Hainer et al., 2006, Schubert and Randler, 2008, Hays and Roberts, 2008, Hays et al., 2002, Provencher et al., 2007, Bellisle et al., 2004); but greater increases in restraint and/or decreases in disinhibition over time have been shown to be associated with greater weight loss during interventions (Foster et al., 1998, Teixeira et al., 2010). Both disinhibition and restraint measures assess an individual's tendency to control their own behaviour around food. However, these measures may reflect a combination of cognitive factors. An individual who is able to resist available food may do so in the context of a very strong urge to consume, and therefore require considerable self-control. They may, on the other hand, not experience a strong urge to consume in the presence of food, and therefore require little self-control in order to resist consumption. One might therefore expect that two individuals scoring equally on disinhibition or restraint might achieve this through very different balances of motivation and impulsivity; for example individuals who reported having high levels restraint only over-ate on a bogus taste test when they also had high levels of impulsivity (Jansen et al., 2009). Furthermore, inducing impulsivity in both high and low restrained eaters demonstrated that the more restrained the participants were, the more

susceptible they were to the induced impulsivity and the more calories they consumed following this induction (Guerrieri et al., 2009).

More recent research has also considered measures of hedonic hunger. Hedonic hunger is measured by the Power of Food Scale (Lowe et al., 2009), which consists of three subscales that are designed to assess an individual's responsiveness to food when it is: not present (e.g., thinking about food even when not physically hungry), present (e.g., seeing or smelling a food), or tasted (e.g., anticipation before eating). While there is an unclear relationship between hedonic hunger and BMI (Ullrich et al., 2013b, Schultes et al., 2010, Lowe et al., 2009, Cappelleri et al., 2009), hedonic hunger has been shown to decrease during a weight loss intervention (O'Neil et al., 2012). There is also an unclear relationship between eating behaviours and hedonic hunger as studies suggest a positive association between hedonic hunger and disinhibition (Lowe et al., 2009), a positive association between hedonic hunger and TFEQ hunger (Lowe et al., 2009), but no significant association between TFEQ restraint and hedonic hunger (Didie, 2001).

Impulsivity is a multi-dimensional construct of self-control, consisting of a disregard of the future consequences, sensitivity to reward and the inability to inhibit impulsive behaviours (Guerrieri et al., 2007) and therefore is measured by several questionnaires or tasks. The most commonly self-reported measure used is the Barratt Impulsiveness Scale (BIS-11) (Patton et al., 1995) and a common computerised task used is the, which is a measure of response inhibition (impulse control) (Logan et al., 1984). The BIS-11 scale and Stop Signal Task are said to be measures of trait impulsivity (Guerrieri et al., 2007). Impulsivity (measured using the BIS-11) has been shown to be positively associated with BMI (Yeomans et al., 2008) and impulsivity is positively related to TFEQ

disinhibition and hunger, but not to restraint (Yeomans et al., 2008, Lyke and Spinella, 2004). While the previous work that I described in Chapter 1 has also demonstrated a significant positive correlation between hedonic hunger and disinhibition, it is not currently known how this relationship may be modulated by an individual's level of impulsivity.

An additional cognitive factor contributing to consumption regulation is memory for recent meals. Damage to episodic memory results in dysregulated consumption in both human patients (Rozin et al., 1998b, Hebben et al., 1985) and rodent models (e.g. Clifton et al., 1998, Davidson et al., 2009). In healthy individuals, manipulation of the quality of memory for recent meals has substantial influence on the long-term satiating effect of those meals (e.g. Higgs et al., 2008, Oldham-Cooper et al., 2011, Higgs and Donohoe, 2011). Indeed, when actual levels of consumption are decoupled from remembered consumption, it is the latter that better predicts later feelings of hunger (Brunstrom et al., 2012). Memory for food consumed declines rapidly after consumption (e.g. Fries et al., 1995), and thus it is possible that relative vividness of memory for previous consumption may be used as a cognitive “shortcut” cue for current metabolic need in circumstances where physiological homeostatic information is ambiguous or unclear. Such a possibility may suggest that individuals with poorer episodic memory ability may be less able to regulate consumption, and therefore more vulnerable to overeating and obesity. This account is supported by evidence that obesity is associated with reduced memory ability in humans (Gunstad et al., 2006, Cournot et al., 2006) and rodents (Winocur et al., 2005, Popovic et al., 2001, Molteni et al., 2002, Jurdak et al., 2008, Valladolid-Acebes et al., 2011). Research on food caching chickadees has shown that birds kept on unpredictable food regimes gain body fat and show impoverished memory

performance, and that those adapted to harsh environments in which food is scarce have evolved enlarged hippocampi and enhanced memories (Pravosudov and Clayton, 2001, Pravosudov and Clayton, 2002, Pravosudov et al., 2002a, Pravosudov et al., 2001, Pravosudov et al., 2002b, Pravosudov et al., 2003). However, the directionality of this relationship is unclear, and it has been argued that it is the obesity itself, alongside conditions associated with obesity such as insulin resistance, hypertension and sleep apnoea, that are the cause of deficits in learning and memory (Kilander et al., 1998, Décary et al., 2000, Cheke et al., 2017, Lampton et al., 2014). Given the potential role of memory ability in contributing to the long-term satiating effect of recent meals, and negative association between memory ability and BMI, it might be predicted that memory ability may contribute to individual differences in eating behaviours. In particular, it is possible that individuals with weak representations of previous meals may be more susceptible to higher levels of hunger as they have fewer signals indicating lack of metabolic need.

While a weak memory for a previous meal may lead to higher levels of hunger, a pre-clinical study in rats has suggested that feeling hungry could actually be helpful for improving memory, as the hormone ghrelin, which was injected into rats, binds to neurons in the hippocampus, which stimulates appetite and is also the area involved in memory formations. They found that rats injected with the highest dose of ghrelin had a 20-30% improved performance on behavioural memory tasks such as maze and avoidance tasks. Thus, the rats that were more “hungry” had an improved memory (Diano et al., 2006). In humans, an individual’s current hunger status is also suggested to influence measures of self-report questionnaires, such as the external eating scale on the Dutch eating behaviour questionnaire (DEBQ) (Evers et al., 2011). External eating

is a measure of the tendency to overeat in response to external food-related cues, regardless of one's physical need for food (Rodin, 1980, Van Strien et al., 1995), similar to the TFEQ disinhibition scale. One study found that hungry participants scored higher in the external eating scale, but not on the restraint or hunger scales. However, the design of this study was a between-subject analysis and therefore the two groups may have had subtle differences which can skew data (Evers et al., 2011). It is also possible that an individual's current hunger status could not only influence motivational factors but also influence an individual's cognition. Indeed, studies have found that an increase in impulsivity was related to an increase in food intake, only when feeling hungry (Nederkoorn et al., 2009). Given this evidence, the differences would be highly relevant to the impact of cognitive and motivational factors, such as memory, impulsivity and hedonic hunger on eating behaviours and thus will be explored within-subjects in this study.

4.2 Aims and Hypotheses

Aims	Predictions
Primary	
To investigate the extent to which variance in the different eating behaviours are predicted by cognitive (impulsivity and memory) and motivational (hedonic hunger) factors.	It is predicted that TFEQ disinhibition and TFEQ hunger will be positively associated with impulsivity, hedonic hunger and memory, whereas TFEQ restraint will be negatively associated with impulsivity, hedonic hunger and memory.
Secondary	
To investigate the extent to which variance in BMI is predicted by eating behaviours (TFEQ scores) and whether these factors interact or modulate one another in that association.	It is predicted that disinhibition and hunger will be positively associated with BMI and that there will be a negative association between restraint and BMI. There may also be an interaction between disinhibition and restraint on BMI.
To explore whether the association between eating behaviours and BMI are explained by cognitive and motivational factors.	It is predicted that there may be an interaction between disinhibition and impulsivity on BMI, an interaction between disinhibition and hedonic hunger on BMI and an interaction between restraint and impulsivity.
To replicate the relationship between episodic memory (using the THT) and BMI.	It is predicted, as shown in a previous study (Cheke et al., 2016) that BMI will be negatively associated with episodic memory.
To investigate whether there are any differences in eating behaviour, cognitive and motivational factors between 'fasted' and 'fed' days (within subjects) in both lean and overweight individuals.	It is predicted that there will be significant differences in TFEQ hunger, disinhibition, restraint, memory and hedonic hunger scores between fasted and fed days. However, given previous evidence it is predicted there will be no significant differences in all measures of impulsivity between fasted and fed sessions.

4.3 Methods

Participants

I recruited 20 Lean ($BMI \geq 18-24.5$) and 20 overweight ($BMI \geq 25.5$) male and female adults aged between 18 and 40 (mean 28.43 ± 5.48) through posters, flyers, online adverts, the Human Nutrition Research (HNR) unit database and word of mouth. Lean and overweight groups were matched for age, gender and IQ, but were significantly different in weight and BMI, as shown in Table 4.1.

Individuals who expressed an interest in the study had an initial screening telephone call or were emailed a form to fill out to ensure that they had no history of excessive drug or alcohol consumption (defined as >21 alcohol units per week for men and >14 units per week for women), no condition or disease such as hypo/hyperthyroidism, diabetes, cardiovascular disease or any mental health/psychiatric disorder (e.g. depression or anxiety). On the first visit, participants were asked to complete the EAT-26 questionnaire to ensure they had no current or previous eating disorder and were considered eligible to take part in the study if they scored ≤ 11 on the questionnaire (Garner et al., 1982). Pregnant or breastfeeding women, those currently following a special weight loss diet (e.g. Atkins, 5:2 or other) or those who had had obesity surgery were excluded. Individuals with severe physical impairments affecting eyesight, hearing or motor performance were also excluded as this may have affected performance on the behavioural tasks. This study was approved by the Cambridge Human Biology Research Ethics Committee.

Study Design

I invited eligible participants to attend the Department of Psychology in the centre of Cambridge on two occasions at lunchtime (approximately 12-2pm). All participants gave written informed consent before taking part. On one of the visits (order counterbalanced between participants) participants were given lunch and then asked to complete a hunger VAS scale to measure their current hunger and fullness (the questionnaire can be found in Appendix 6) following the lunch as well as questionnaires and computer tasks (“fed” session), while on the other visit they were asked to complete the questionnaires and computer tasks first before being given the VAS hunger scale (Appendix 6) and finally given lunch to take away with them (“fasted” session). Those on the “fasted” session had been asked to eat their normal breakfast before 8am and to restrain from eating before the visit, while those on the “fed” session were told to eat normally before the visit. Nonetheless, at each session participants were asked to record what they already ate that day and at what time. Each of the two sessions lasted approximately 2 hours and participants were compensated £40 (plus travel expenses) after completing the study.

Tasks and Questionnaires

Raven’s Advanced Progressive Matrices

The set II of the Raven’s advance progressive matrices was used as a measure of IQ (Raven and Lewis, 1962). Participants were given a time limit of 40 minutes to complete the 36-question test. Test scores were marked out of a possible total of 36.

Hunger and Fullness Visual Analogue Scale (VAS)

In order to assess and confirm the level of current hunger status during the fasted and fed sessions, subjects completed a visual analogue scale (VAS) of 100mm long to answer the questions “how hungry are you right now?” with “Not at all Hungry” scoring zero

and “Extremely hungry” scoring 100 and “how full are you right now?” with “Not at all Full” scoring zero and “Extremely Full” scoring 100. The scale was completed at both sessions, before lunch in the fasted session and after consuming lunch in the fed session. The scale can be found in Appendix 6.

Three Factor Eating Questionnaire (TFEQ)

The TFEQ (Stunkard and Messick, 1985) was used to measure dietary restraint, disinhibition and hunger, as previously described in Chapter 3. The questionnaire can be found in Appendix 3.

Power of Food Scale (PFS)

The PFS (Lowe et al., 2009) was used to measure hedonic hunger, as previously described in Chapter 2. The questionnaire can be found in Appendix 2.

The Barratt Impulsiveness Scale (BIS-11)

The BIS-11 is a self-report, 30-item questionnaire assessment of impulsivity (Patton, 1995). It is also able to determine three distinct areas of impulsivity, including motor impulsivity, non-planning impulsivity and attentional impulsiveness. Motor impulsivity involves a need for movement leading to hyperactivity. Non-planning impulsivity involves a lack of reflection leading to impulsive attitudes and conclusions. Attentional impulsivity refers to rapid shifts in the focus of attention. Thus, an individual’s impulsivity may be a combination of these factors of impulsivity. The questionnaire can be found in Appendix 4.

Stop Signal Task (SST)

The Cambridge Cognition (CANTAB) SST is a measure of response inhibition (impulse control) (Logan, 1994). The task is approximately 20 minutes long and is split into two parts. The first part is an introduction to the press pad response box, in which

participants respond to an arrow stimulus by pressing one of two choices on a button box depending on which way the arrow points (left or right). At the beginning of this there is a block of 16 trials for practice. In the second part, if an audio sound plays then the subject must inhibit the response (not press the button) for the current arrow stimuli. The stop signal reaction time (SSRT) is calculated by subtracting the delay between the go stimulus and the stop signal (stop delay) from the reaction time (Logan et al., 1997). The longer the SSRT, the more impulsive a participant is said to be.

The 'Treasure-Hunt' task

The THT is a computerised episodic memory task, testing memory for item (What), location (Where) and temporal order (When) as well as the ability to integrate these into a single coherent representation (WWW) (Cheke, 2016, Cheke et al., 2016). An initial training task was given using images of children's toys. The main task contained a fixed order of sections: encoding, WWW, where, what and when, as shown in Figure 4.1. The encoding section required participants to hide a number of food items in a 2D complex scene using the arrows on the keyboard and pressing enter to "hide" the item. Specific instructions for this part of the task included: not hiding images in the corners of the screen, ensuring the image did not go off the screen and to use the "scene, not the screen" when choosing a hiding location. Participants were instructed to hide the object in a different place across two hiding periods, labelled "day 1" and "day 2", and occurring approximately 5 minutes apart. There were two different scenes for each encoding period, such that the order went scene 1, day 1 - scene 1 day 2 - scene 2 day 1 – scene 2 day 2. The WWW recall period required participants to move the item back to the place they had hidden it on a given day and scene. This requires integration of the three elements "where" (location of the object they hid), "what" (which object they hid) and

“when” (which day they had hidden that object in that location). “WWW” accuracy was calculated as the proportion of items the participants re-hid in the correct place for the indicated day. This was followed by “where” questions which required participants to answer ‘Yes’ or ‘No’ to as whether they had hidden an item in a location in the scene marked by a cross. Half of the locations indicated were where participants had hidden an object and half were locations they had not hidden anything. The “What” questions required participants to identify objects they had hidden by answering ‘Yes’ or ‘No’ a series of items, half of which they had hidden and half of which they had not seen before. The accuracy on both the “Where” and “What” tasks required calculating d' from the proportion of correctly identified “old” items/locations against new items identified as old (false alarms). The final section was the “When” questions, which required participants to indicate using the left or right arrow which of the two items presented on the screen they had hidden first. The “When” task accuracy required calculating d' from the proportion of correct answers against the proportion of incorrect items. Formulas for d' calculation were taken from Macmillan & Creelman (Macmillan and Creelman, 1990). There were 6 sessions in total and participants completed 3 tasks on each of the sessions, including one from each of the “Easy” (4 items, 8 hiding events), “Medium” (8 items, 16 hiding events) and “Hard” (12 items, 24 hiding events) tasks in random order, counterbalanced across individuals. The task was run using PsychoPy (Peirce, 2007) . The Treasure-Hunt task has been found to be a sensitive measure of individual differences in episodic memory, and has been used to demonstrate distinct patterns of deficits in older adults (Cheke, 2016) and overweight young adults (Cheke et al., 2016).

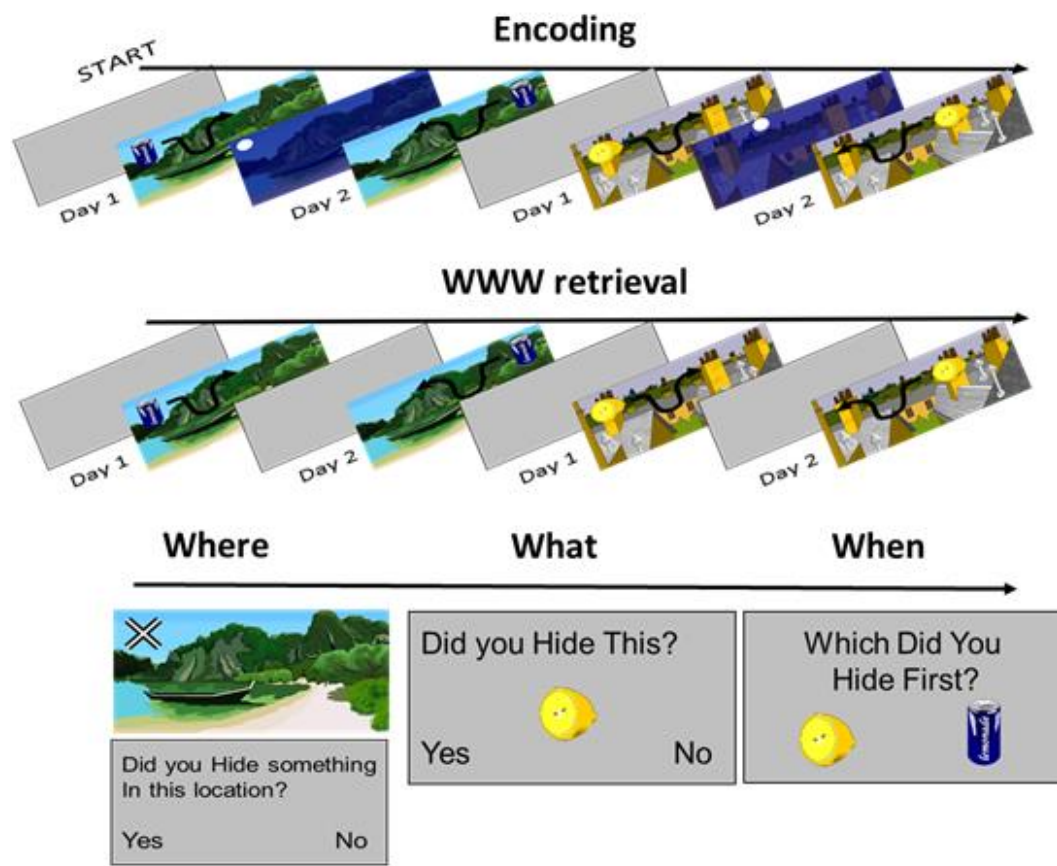


Figure 4.1: Description of the Treasure-Hunt task, similar figure to the one published in Cheke, et al., 2016 (Cheke et al., 2016).

Statistical Analysis

Comparison of differences of all variables across gender, age and BMI or fasted status (fasted vs. fed). Correlations between variables were made using either Student's T test or Pearson's correlation analysis and where appropriate were corrected for multiple comparisons, using Sidak's correction method (Šidák, 1967). Repeated measures analysis of variance (RMANOVA) models were used to investigate the main effects and interaction of BMI and fasted status on the measures of memory, with difficulty and fasted status as within-subjects factors and BMI as a between subject covariate.

Linear regression models were used to investigate the association between BMI and eating behaviours, cognitive and motivational factors, BMI was entered into models as the dependant variable, and all eating behaviour, cognitive and motivational factors were entered into the model as independent variables. To investigate the association between eating behaviours and cognitive/motivational factors, linear regression models were used with all TFEQ scores as dependent variables in each model and all cognitive and motivational factors as the independent variables. The StepAIC function from the MASS package in R was used to select the best model fit by minimizing Akaike's information criterion (AIC) (Venables, 2002). Forward and backward model selections were implemented to allow for interactions between variables. To focus on cognitive/motivational factors as predictors eating behaviours beyond the contribution attributable to gender, age, IQ and BMI, these variables were adjusted for in all the regression models. Analyses were performed using the R statistical programme (R, 2008) (Version 3.1.2, R).

4.4 Results

Demographic associations

Participant demographics are described in Table 4.1. There were significant differences in the BIS-11 total score and two of its subscales (non-planning and motor) between males and females. Females on average were significantly more impulsive than males in all cases (BIS11: $t(27)=2.097$, $p=0.045$, BIS11 non-planning: $t(31)=2.269$, $p=0.030$, BIS11 motor: $t(25)=2.193$, $p=0.038$). There were no significant differences between men and women in "WWW", "When" or "Where" subtasks of THT (WWW: $t(23)=-0.473$, $p=0.641$,

“Where”: $t(21)=1.333$, $p=0.197$, “When”: $t(29)=1.065$, $p=0.296$), however women had slightly greater recall accuracy than men in the “What” subtask ($t(21)=2.147$, $p=0.043$).

There were no significant correlations between age and any of the eating behaviour or impulsivity measures. There was a significant negative association between age and the “Where” ($r(38)=-0.458$, $p=0.002$) and “When” ($r(38)=-0.484$, $p=0.002$) subtasks of the THT. The older the participant the poorer the performance on these tasks. There was no significant association of age with the overall “WWW” ($r(38)=-0.177$, $p=0.276$) or “What” ($r(38)=-0.031$, $p=0.848$) subtasks.

IQ was significantly negatively related to age ($r(38)=-0.513$, $p<0.001$), but not to BMI ($r(38)=-0.274$, $p=0.087$). There was a significant negative correlation between IQ and the BIS11 non-planning subscale ($r(38)= -0.471$, $p=0.002$). However, there were no other correlations between IQ and any of the other eating behaviour or impulsivity scores. There was a significant positive correlation between IQ and the “WWW”, “Where” and “When” subtasks of the THT (“WWW”: $r(38)=0.603$, $p<0.001$, “Where”: $r(38)=0.412$, $p=0.008$, “When”: $r(38)=0.486$, $p=0.001$), but there was no significant correlation between IQ and the “What” subtask ($r(38)=0.139$, $p=0.392$). Given the associations with gender, age and IQ these variables were controlled for in further analyses.

Table 4.1: Participant demographics when grouped by BMI (left) or hunger state (right)			
Variable	Mean (SD)		Group differences T-value (df) P-value^a
	Lean Group (BMI <24.5)	Overweight Group (BMI >25.5)	
Age (years)	26.80 (4.80)	30.05 (6.29)	-1.942 (33) 0.061
Weight (kg)	63.38 (9.00)	83.29 (10.43)	-6.466 (37) <0.001
BMI (kg/m²)	21.46 (2.34)	28.00 (2.10)	-9.291 (38) <0.001
Gender (F:M)	16:4	11:9	(1.823) ^b 0.177
IQ (Ravens test, out of 32)	27.95 (4.35)	25.15 (6.29)	1.639 (34) 0.111
a= welch two sample t-test, differences between lean and overweight groups; b=chi-squared test			

A significant positive correlation was seen between BMI and TFEQ disinhibition ($r(38)=0.430$, $p=0.006$) and restraint scores ($r(38)=0.333$, $p=0.036$; Figure 4.2). However, these relationships did not survive correction for multiple comparisons (alpha adjusted to 0.0042). There were no other correlations with BMI for any of the other eating behaviour, hedonic hunger or impulsivity scores, as shown in Table 4.2.

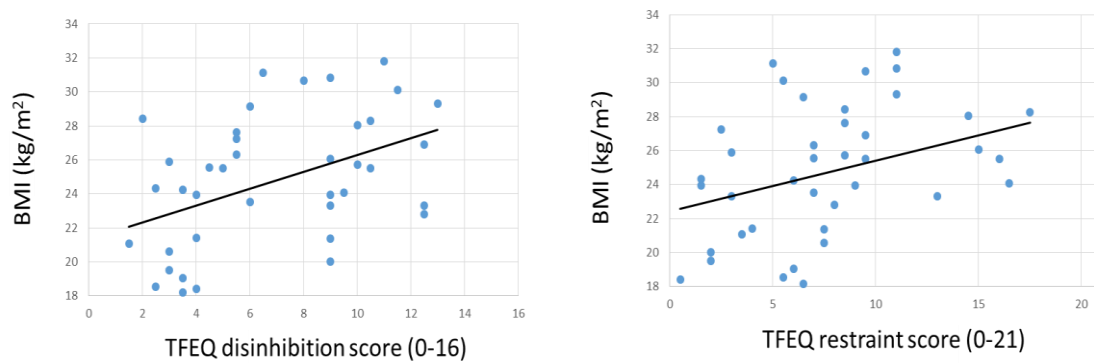


Figure 4.2: Scatter plots for TFEQ disinhibition (left) and restraint scores (right) with BMI

Associations between eating behaviours, hedonic hunger and impulsivity

Table 4.3 shows the relationship between each of the eating behaviour and impulsivity scores. Pearson's correlation analysis corrected for Sidak's multiple comparisons (alpha adjusted to 0.0046) revealed several significant correlations between variables. A positive correlation was seen between TFEQ disinhibition and restraint. TFEQ disinhibition scores were also positively correlated with the BIS-11 total score and two of its subscales as well as the PFS total score and all three of the PFS subscales. TFEQ hunger scores were positively correlated with the PFS total scores and the PFS available and present subscales. The BIS-11 total score was positively correlated with all three of its subscales and two of the BIS-11 subscales (motor and non-planning) were positively correlated with one another, but were not correlated with the attentional subscale. The BIS-11 motor subscale was also positively correlated with the PFS present subscale. The PFS total score and the three subscales (available, tasted and present) were all significantly correlated with one another. The SSRT scores correlated with none of the eating behaviour questionnaire scores nor the BIS-11 scale.

Table 4.2: Participant mean (SD) scores for eating behaviours and impulsivity scores and the group differences when grouped by BMI (left) or hunger state (right)

Variable	Mean (SD)		Correlation with BMI (R value) df=38, P-value ^a	Mean (SD)		Group differences (T-value), df=39 P-value ^b
	Lean	Over-weight		Fasted session	Fed session	
TFEQ disinhibition	5.85 (3.45)	7.92 (3.21)	(0.430) 0.006**	6.92 (3.36)	6.85 (3.76)	(0.267) 0.791
TFEQ restraint	6.15 (4.24)	9.32 (4.10)	(0.333) 0.036*	8.00 (4.44)	7.47 (4.70)	(1.445) 0.157
TFEQ hunger	5.88 (2.85)	6.20 (2.74)	(0.134) 0.410	6.15 (2.98)	5.92 (3.00)	(0.621) 0.538
PFS total	2.58 (0.67)	2.56 (0.74)	(0.124) 0.445	2.64 (0.72)	2.49 (0.74)	(1.982) 0.055
PFS available	2.18 (0.83)	2.20 (0.85)	(0.136) 0.403	2.23 (0.89)	2.15 (0.84)	(0.893) 0.377
PFS tasted	2.77 (0.76)	2.71 (0.78)	(0.074) 0.648	2.85 (0.82)	2.63 (0.77)	(2.761) 0.009
PFS present	2.93 (0.88)	2.89 (0.76)	(0.104) 0.523	2.99 (0.83)	2.83 (0.93)	(1.608) 0.116
BIS-11 total	51.73 (9.54)	52.55 (12.15)	(0.129) 0.429	62.75 (11.74)	63.52 (10.56)	(-0.854) 0.398
BIS-11 non-planning	14.95 (4.67)	16.82 (7.27)	(0.198) 0.222	23.73 (7.16)	24.05 (5.69)	(-0.481) 0.633
BIS-11 motor	22.07 (3.75)	21.57 (3.96)	(0.018) 0.914	22.88 (4.03)	22.77 (3.87)	(0.313) 0.756
BIS-11 attentional	14.70 (3.55)	14.15 (3.04)	(0.348) 0.831	16.15 (3.36)	16.70 (3.51)	(-1.657) 0.106
SSRT	156.61 (42.42)	153.98 (47.90)	(-0.109) 0.504	154.35 (44.22)	157.69 (54.76)	(0.270) 0.789

a= Pearson's product moment correlation test, association with BMI; b= Within subject differences between fasted and fed session, Paired students t- tests

Table 4.3: Pearson's correlation analysis between eating behaviour, hedonic hunger and impulsivity scores

Variable		TFEQ disinhibition	TFEQ hunger	BIS11 total	BIS11 attentional	BIS11 motor	BIS11 non- planning	SST	PFS total	PFS available	PFS tasted	PFS present
TFEQ restraint score (0-21)	Pearson Cor.	0.579	0.116	0.094	0.080	0.193	0.002	0.028	0.351	0.433	0.263	0.158
	Sig. (2-tailed)	<0.001	0.477	0.565	0.623	0.232	0.990	0.865	0.026	0.005	0.101	0.329
TFEQ disinhibition score (0-16)	Pearson Cor.		0.389	0.480	0.463	0.501	0.287	-0.163	0.647	0.643	0.473	0.543
	Sig. (2-tailed)		0.013	0.002	0.003	0.001	0.072	0.316	<0.001	<0.001	0.002	<0.001
TFEQ hunger score (0-14)	Pearson Cor.			0.387	0.420	0.269	0.290	-0.172	0.500	0.498	0.295	0.499
	Sig. (2-tailed)			0.014	0.007	0.093	0.070	0.289	0.001	0.001	0.065	0.001
BIS11 total score (0-30)	Pearson Cor.				0.662	0.825	0.897	-0.039	0.304	0.238	0.241	0.330
	Sig. (2-tailed)				<0.001	<0.001	<0.001	0.813	0.057	0.138	0.134	0.038
BIS11 attentional subscale	Pearson Cor.					0.412	0.377	-0.225	0.337	0.426	0.249	0.140
	Sig. (2-tailed)					0.008	0.017	0.163	0.033	0.006	0.122	0.389
BIS11 motor subscale	Pearson Cor.						0.612	0.120	0.344	0.214	0.272	0.458
	Sig. (2-tailed)						<0.001	0.462	0.030	0.184	0.089	0.003
BIS11 non-planning subscale	Pearson Cor.							-0.023	0.141	0.059	0.122	0.221
	Sig. (2-tailed)							0.890	0.384	0.718	0.453	0.170
SST score	Pearson Cor.								0.099	-0.025	0.238	0.080
	Sig. (2-tailed)								0.542	0.879	0.139	0.623
PFS total score	Pearson Cor.									0.888	0.886	0.820
	Sig. (2-tailed)									<0.001	<0.001	<0.001
PFS available subscale	Pearson Cor.										0.658	0.554
	Sig. (2-tailed)										<0.001	<0.001
PFS tasted subscale	Pearson Cor.											0.674
	Sig. (2-tailed)											<0.001

The relationship between BMI, eating behaviours, cognitive and motivational factors

To investigate the nature of the relationship between BMI, eating behaviours and cognitive and motivational factors, five linear regression analyses were conducted. Models 1-3 assessed the extent to which eating behaviours are predicted by cognitive and motivational factors: TFEQ scores were the dependant variables in each model and all cognitive (impulsivity and memory) scores and motivational (hedonic hunger) scores were entered as independent variables. Model 4 assessed the contribution of eating behaviours in the variance of BMI: BMI was the dependent variable and all TFEQ eating behaviour scores were entered as independent variables. Finally, model 5 assessed the extent in which the association between eating behaviours and BMI may be explained by cognitive and motivational factors: BMI was the dependent variable and all eating behaviour, cognitive and motivational factors were independent variables with interactions between eating behaviour scores and cognitive/motivational factors were also entered into the model. All best-fit models from the stepAIC selection process were adjusted for age, gender and IQ.

As shown in Table 4.4, in model 1, the TFEQ disinhibition score was best fit by a model containing the TFEQ restraint score, PFS total score, SST score and BIS-11 total score, which predicted 72% of variance in TFEQ disinhibition. There was a positive association between disinhibition and the PFS total score, TFEQ restraint score and BIS-11 total score. Whereas there was a negative association between disinhibition and the SST score.

In model 2, the best fit model for the TFEQ restraint score contained the TFEQ disinhibition score, “WWW” score and BIS-11 total score, and predicted 43% of variance.

There was a positive association between TFEQ restraint and TFEQ disinhibition score. However, there was no association between restraint and the “WWW” score or BIS-11 total score. Finally, in model 3, the best fit model for the TFEQ hunger score contained the PFS total score, SST score and BIS-11 total score, which predicted 37% of variance in TFEQ hunger score. There was a positive association between TFEQ hunger and the PFS total score, but no association between TFEQ hunger and the SST or BIS-11 scores.

Model 4, which contained BMI as the dependent variable and TFEQ scores as the independent variables, produced a best-fit model containing only TFEQ disinhibition score. This model predicted 38% of variance in BMI, with TFEQ disinhibition being positively associated with BMI. In model 5, with BMI as the dependent variable and all eating behaviour, cognitive and motivational factors as independent variables, a best-fit model containing TFEQ disinhibition score, PFS total score and “WWW” score scores predicted 52% of the variance in BMI. As in the previous model, the TFEQ disinhibition score was positively associated with BMI. However, the PFS total and “WWW” scores were not associated with BMI. There were no significant interactions between eating behaviour, cognitive and motivational variables on BMI.

Table 4.4: Regression analysis models for TFEQ scores and BMI						
Model (dependent variable)	R ²	Adjusted R ²	Independent variables	β(SE)	T-value	P- value
Model 1: Disinhibition	0.71	0.65	TFEQ restraint	0.323 (0.08)	4.075	<0.001
			BIS-11 total	0.113 (0.04)	3.220	0.003
			PFS total	2.285 (0.53)	4.274	<0.001
			SST	-0.016 (0.01)	-2.118	0.042
Model 2: Restraint	0.43	0.33	TFEQ disinhibition	0.821 (0.20)	4.119	<0.001
			“WWW”	-6.587 (4.89)	-1.347	0.187
			BIS-11 total	-0.078 (0.07)	-1.055	0.299
Model 3: Hunger	0.37	0.26	BIS-11 total	0.074 (0.04)	1.794	0.082
			PFS total	1.810 (0.59)	3.056	0.004
			SST	-0.014 (0.01)	-1.607	0.117
Model 4: BMI with TFEQ scores only	0.38	0.31	TFEQ disinhibition	0.557 (0.16)	3.577	0.001
Model 5: BMI with all eating behaviour, cognitive and motivational scores	0.52	0.43	TFEQ disinhibition	0.685 (0.20)	3.499	0.001
			PFS total	-1.749 (0.96)	-1.819	0.078
			“what” d’	-4.283 (2.87)	-1.494	0.145
			“WWW”	-5.589 (3.28)	-1.704	0.097
All models were controlled for age, gender, BMI and IQ						

Replicating the relationship between episodic memory and BMI

Performance on each subtask of the Treasure-Hunt task was assessed using repeated measures ANOVA with BMI and difficulty as between and within subjects' variables, respectively and controlled for age, gender and IQ. There was a significant negative main effect of BMI on performance of all memory measures ("WWW": $F(1,5)=17.496$, $p<0.001$, "What": $F(1,5)=10.906$, $p=0.001$, "Where": $F(1,5)=10.301$, $p=0.002$, "When": $F(1,5)=19.766$, $p<0.001$). Thus, the higher the BMI the poorer the performance on all subtasks of the Treasure-Hunt task (Figure 4.3). There was also a main effect of difficulty: performance significantly reduced with increasing difficulty in the "WWW", "what" and "where" subtasks ("WWW": $F(1,5)=22.537$, $p<0.001$, "What": $F(1,5)=7.669$, $p<0.001$, "Where": $F(1,5)=21.657$, $p<0.001$), but not in the "when" subtask ("When": $F(1,5)=1.585$, $p=0.207$), as shown in Figure 4.4. However, there was no interaction between BMI and the level of difficulty in any of the subtasks ("WWW": $F(1,5)=0.276$, $p=0.759$, "What": $F(1,5)=1.531$, $p=0.219$, "Where": $F(1,5)=0.300$, $p=0.741$, "When": $F(1,5)=0.337$, $p=0.714$).

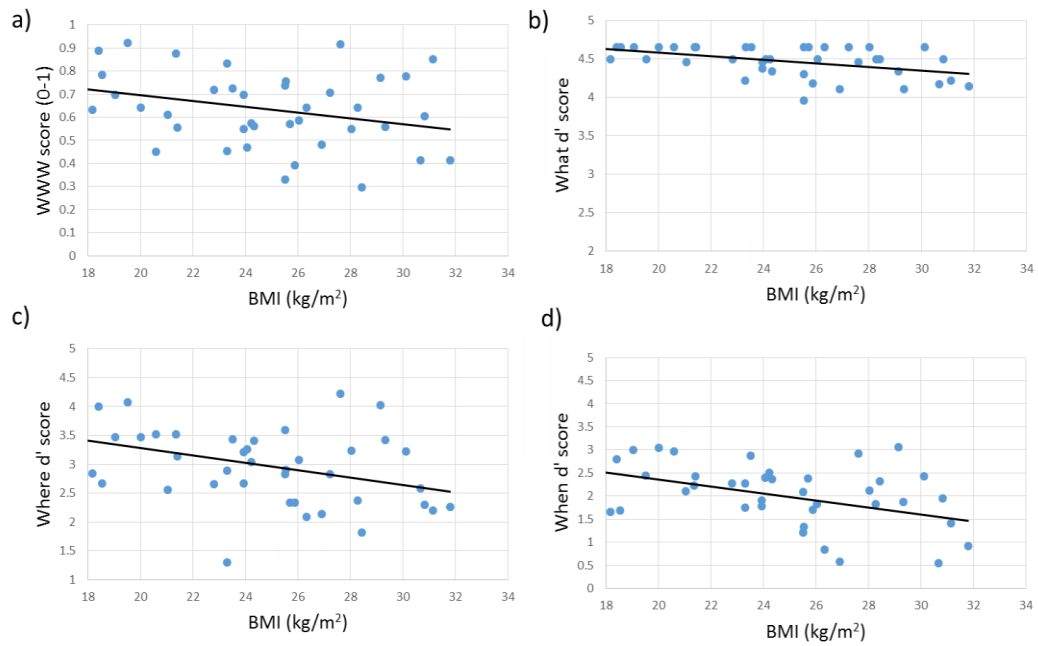


Figure 4.3: Scatter plots for correlation between BMI and a) WWW, b) What, c) Where and d) When

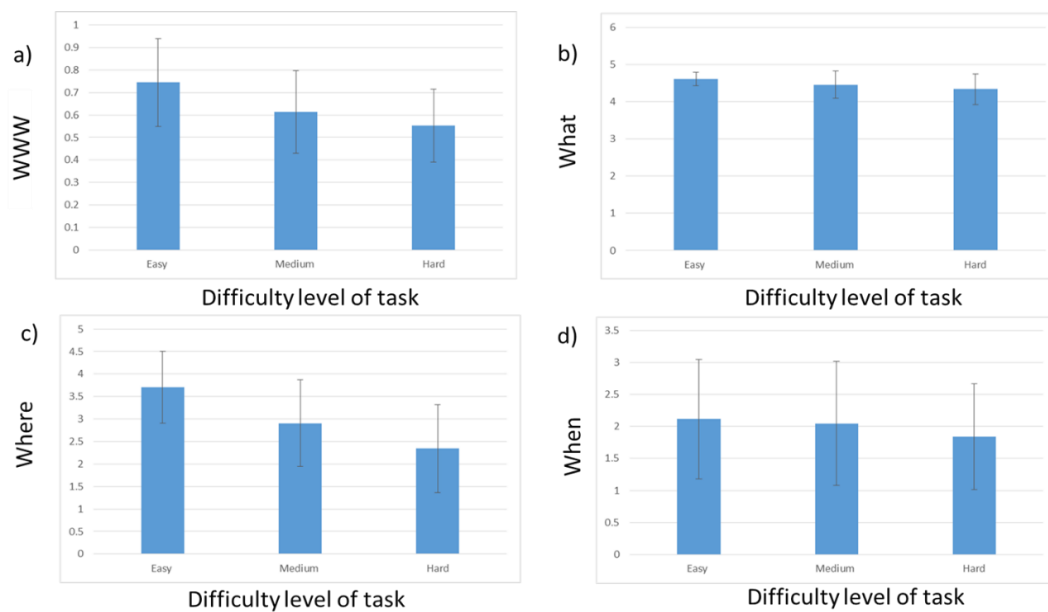


Figure 4.4: Bar charts for mean and standard deviations to show the differences in scores between difficulty levels for a) WWW, b) What, c) Where and d) When

The effect of hunger status on eating behaviours, cognition and motivation

Paired t-tests revealed a significant difference between the level of hunger (measured using the hunger/fullness VAS scale) between the fasted and fed sessions ($t(39) = 19.145$, $p < 0.001$) and a significant difference between reported fullness between fasted and fed sessions ($t(39) = -13.651$, $p < 0.001$), as shown in Figure 4.5.

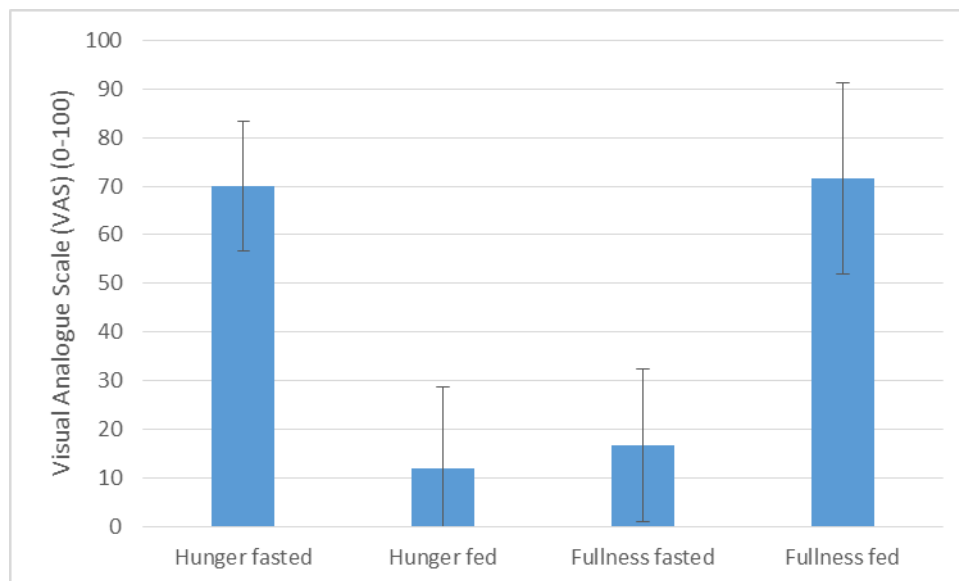


Figure 4.5: Bar chart to show the mean and standard deviations for reported hunger and fullness VAS scores between fasted and fed sessions

Pearson's correlations, corrected for multiple comparisons ($\alpha = 0.0042$) revealed no significant correlation between hunger or fullness (measured using the hunger and fullness VAS scale) and the eating behaviour, hedonic hunger or impulsivity, as shown in Table 4.5. Furthermore, within-subject analysis using paired t-tests, corrected for multiple comparisons ($\alpha = 0.0042$), revealed no significant difference in any of the impulsivity, hedonic hunger or eating behaviour measures between fasted and fed sessions, as shown in Table 4.5. Because there were no significant differences between

the fasted and fed sessions or any relationships with hunger status, the eating behaviour, hedonic hunger and impulsivity scores were averaged for all analyses.

Table 4.5: Pearson's correlation between hunger/fullness VAS scale scores and eating behaviour, hedonic hunger and impulsivity measures on fasted and fed sessions

Variable		Hunger VAS score		Fullness VAS score	
		Fasted session	Fed session	Fasted session	Fed session
TFEQ disinhibition	Pearson's correlation	0.032	-0.283	-0.067	0.234
	P-value	0.845	0.077	0.680	0.145
TFEQ restraint	Pearson's correlation	0.228	-0.257	-0.101	0.166
	P-value	0.156	0.109	0.535	0.307
TFEQ hunger	Pearson's correlation	0.358	0.336	0.130	-0.054
	P-value	0.023	0.034	0.422	0.743
PFS total	Pearson's correlation	0.298	0.185	-0.233	-0.108
	P-value	0.061	0.252	0.148	0.508
PFS available	Pearson's correlation	0.178	0.092	-0.166	-0.064
	P-value	0.273	0.574	0.308	0.697
PFS tasted	Pearson's correlation	0.238	0.076	-0.246	0.028
	P-value	0.139	0.643	0.126	0.864
PFS present	Pearson's correlation	0.396	0.354	-0.191	-0.267
	P-value	0.011	0.025	0.238	0.959
BIS-11 total	Pearson's correlation	-0.094	-0.024	0.173	0.052
	P-value	0.563	0.881	0.286	0.752
BIS-11 non-planning	Pearson's correlation	-0.114	-0.001	0.135	0.129
	P-value	0.483	0.995	0.405	0.427
BIS11 motor	Pearson's correlation	0.089	0.045	0.070	-0.002
	P-value	0.587	0.784	0.666	0.991
BIS-11 attentional	Pearson's correlation	-0.192	-0.121	0.231	-0.052
	P-value	0.236	0.457	0.152	0.750
SSRT	Pearson's correlation	0.067	0.305	-0.167	-0.235
	P-value	0.680	0.059	0.302	0.150

To assess the impact of current hunger state on episodic memory, a repeated measure analysis of variance (RMANOVA) was conducted with fasted status and difficulty as within subject factors, controlled for age, gender and IQ. There was no main effect of fasted status in any of the memory tasks (“WWW”: $F(1,2) = 0.476$, $p = 0.491$, “What”: $F(1,2) = 0.009$, $p = 0.924$, “Where”: $F(1,2) = 0.033$, $p = 0.857$, “When”: $F(1,2) = 0.996$, $p = 0.327$). There was a significant main effect of difficulty on the “WWW”, “What” and “Where” (“WWW”: $F(1,2) = 21.867$, $p < 0.001$, “What”: $F(1,2) = 7.342$, $p < 0.001$, “Where”: $F(1,2) = 21.513$, $p < 0.001$) but not in the “When” subtask (“When”: $F(1,2) = 1.557$, $p = 0.213$). There was no interaction between fasted status and difficulty in any of the subtasks (“WWW”: $F(1,2) = 0.267$, $p = 0.766$, “What”: $F(1,2) = 0.435$, $p = 0.648$, “Where”: $F(1,2) = 0.206$, $p = 0.814$, “When”: $F(1,2) = 0.168$, $p = 0.846$).

To assess possible interactions between BMI and fasted status on memory, a RMANOVA was conducted with BMI and fasted status as between and within subject variables, respectively and controlled for age, gender and IQ. In this model there was a significant negative main effect of BMI on performance of all memory tasks (“WWW”: $F(1,1) = 17.067$, $p < 0.001$, “What”: $F(1,1) = 10.798$, $p = 0.001$, “Where”: $F(1,1) = 10.289$, $p = 0.002$, “When”: $F(1,1) = 19.934$, $p < 0.001$). However, there was no significant main effect of fasted status in any of the memory tasks (“WWW”: $F(1,1) = 0.453$, $p = 0.502$, “What”: $F(1,1) = 0.010$, $p = 0.919$, “Where”: $F(1,1) = 0.031$, $p = 0.859$, “When”: $F(1,1) = 1.000$, $p = 0.318$). Furthermore, there was no interaction between fasted status and BMI in any of the tasks (“WWW”: $F(1,1) = 0.026$, $p = 0.873$, “What”: $F(1,1) = 0.670$, $p = 0.414$, “Where”: $F(1,1) = 0.468$, $p = 0.495$, “When”: $F(1,1) = 1.020$, $p = 0.291$).

4.5 Discussion

The main aim of this study was to examine the extent to which variance in the different eating behaviours are predicted by cognitive (impulsivity and memory) and motivational (hedonic hunger) factors. The results suggest that individuals with greater impulsivity, as measured by the BIS-11 total score, have more disinhibited eating behaviours (TFEQ disinhibition score) but not higher levels of restraint (TFEQ restraint score). These data confirm and extend the findings of two studies (Yeomans et al., 2008, Lyke and Spinella, 2004), which also showed that impulsivity, specifically the BIS-11 motor score, was associated with the TFEQ disinhibition score and found no association between impulsivity and restraint. The association between disinhibition and impulsivity, however, seems to be complex as there was no association between disinhibition and impulsivity as measured by the SST score. This is in line with a previous study which showed that women scoring higher on the TFEQ disinhibition scale were not more impulsive on a Stop-signal task (Leitch et al., 2013). Despite previous studies reporting an association between attentional impulsivity and hunger (Lyke and Spinella, 2004), my results found no association between impulsivity (measured by either the BIS-11 or SST) and TFEQ hunger scores. These result differences between SSRT and BIS-11 and their relationship with disinhibition scores may be explained by the differences seen in obese between these measures and BMI. Evidence has shown that obese women (compared to lean women) scored higher on the SSRT task, but not on the BIS-11 questionnaire (Patton et al., 1995, Monahan and Steadman, 1994). This might be explained by the nature of the task/questionnaire. Self-report measures, such as the BIS-11 can be biased by lack of self-insight from the participant and the validity of the scores can be

questioned. Whereas, behavioural measures, such as the SST, are more objective and therefore may be more adequate to measures an individual's impulsivity.

This analysis also revealed a positive relationship between hedonic hunger and disinhibited eating and hunger TFEQ scores, but not restraint scores. This finding supports a previous study which also found a positive association between hedonic hunger and both disinhibition and hunger in a sample of 153 female US university students (Lowe et al., 2009). The results extend these previous findings having shown this relationship in both men and women, with no significant differences found between men and women in any of the PFS scores. These results suggest that regardless of gender or BMI, an individual's hedonic hunger may lead to higher levels of hunger and disinhibited eating. My results also support previous findings which reported no significant association between TFEQ restraint and hedonic hunger (Didie, 2001). These results suggest that hedonic hunger, measured by the PFS may reflect a response to appetite in a broader of stimuli, including susceptibility to eating from the environment and food-related and hunger stimuli, beyond that of only restrained eating. Nonetheless, the measures are self-reported and so further work is crucial to test the relationships between eating behaviours using measures other than self-report.

My results also suggest that there is a strong positive association between disinhibited eating (TFEQ disinhibition scores) and restrained eating (TFEQ restraint scores), suggesting that individuals with higher levels of disinhibited eating have higher levels of self-reported restraint and vice versa. An explanation for the positive association between disinhibition and restraint might be because all individuals were included in my analysis, despite BMI being controlled for in my model. Previous studies have suggested

that in lean individuals, greater restraint acts as a risk factor for overeating, whereas in overweight individuals greater restraint may protect against overeating, as the relationship between disinhibition and weight is weakened in individuals with high restraint (Hays et al., 2002, Williamson et al., 1995, Hays and Roberts, 2008, Dykes et al., 2004). Another explanation could be an overload of questionnaires in this study and thus a lack of attention to detail in the questionnaire means that the subjects may not have answered the questions correctly.

The regression outputs gave a very high level of variation in these behaviours, predicted by the cognitive and motivational factors. Although these relatively high R^2 values (0.34-0.71) are useful to summarise the strength of the linear relationship between the eating behaviours and the independent variables and care should be taken to not interpret the R^2 values with a lot of emphasis. The R^2 assumes that each independent variable in the model explains the variation in the dependent variable, whereas the adjusted R^2 gives the percentage of variation explained by only the independent variables which affect the dependent variable. While the R^2 values of this study seem to be relatively high in comparison to previous studies which have reported approximately 15-17% variance in their regression models (Löffler et al., 2015, Lattimore et al., 2011), the adjusted R^2 values seem to also be relatively high (0.26-0.65) suggesting that impulsivity and hedonic hunger explain a relatively high percentage of variance in the eating behaviours.

Whilst the results suggest hedonic hunger and impulsivity contribute to disinhibition, a secondary aim of this study was to investigate whether the eating behaviour, cognitive and motivational factors could predict BMI. My results revealed that TFEQ disinhibition was positively associated with BMI. This positive relationship between BMI and

disinhibition is in line with the results from many studies, as discussed in Chapter 1 (Chaput et al., 2009, Gallant et al., 2010, Hainer et al., 2006, Schubert and Randler, 2008, Hays and Roberts, 2008, Hays et al., 2002, Provencher et al., 2007, Bellisle et al., 2004). Despite some studies reporting a relationship between BMI and hedonic hunger, with obese individuals having higher PFS scores than non-obese individuals (Schultes et al., 2010, Ullrich et al., 2013b), my results only found a slight trend towards a negative association between hedonic hunger and BMI. This does, however, supports previous findings that have also shown no significant correlation between BMI and any of the PFS scale scores (Lowe et al., 2009, Witt et al., 2014). Thus, my results suggest that disinhibited eating behaviours play a major role in obesity. However, given a larger sample of individuals who are more heterogeneous (including dieters) disinhibited eating might not remain as the only factor to be associated with BMI and therefore these factors of eating behaviour should be explored further to fully understand the specific way in which these factors may interact.

Despite there being no interactive effect between eating behaviours, cognitive and motivational factors when predicting BMI previous studies have found several interactions between variables. For example, one study in 133 female university students with a BMI range of 15.11-29.67 kg/m² found an interaction between attentional and motor impulsivity when predicting BMI (Meule and Platte, 2016). In addition, studies have also suggested an interaction between TFEQ restraint and disinhibition domains of eating behaviour when predicting BMI (Löffler et al., 2015, Dietrich et al., 2014). Some studies, for example, Kruger and colleagues split their sample of participants into low and high eating behaviour characteristics, such as High-Restraint-Low-Disinhibition (HRLD) vs. Low-Restraint-High-Disinhibition (LRHD) and

showed that in a group of 116 women those with HRLD, had the lowest BMI scores (mean: 22.3 kg/m²) and those with LRHD had the highest BMI scores (mean: 26.2 kg/m²) (Kruger et al., 2016a). This is an interesting way to group participants, but unfortunately my study did not have an adequate sample size to split the subjects into characteristic groups. There may be a more complex relationship between these factors when predicting BMI, which should be explored further in a larger sample of participants.

Another aim of my study was to replicate the findings from a previous study (Cheke et al., 2016), which showed a negative relationship between BMI and episodic memory. Indeed, as previously reported by Cheke and colleagues, the results of this chapter also found that those with higher BMI had an impaired performance on all measures of the THT including spatial, temporal and item memory, as well as the ability to combine these elements (“What-Where-When” memory). This therefore confirms and extends the previous results from Cheke et al., (Cheke et al., 2016), which suggested that episodic memory deficits in overweight individuals compared to lean individuals could be of concern as there is also evidence to suggest that episodic memory may also influence feeding behaviour and regulation of appetite (Robinson et al., 2013b). However, Cheke and colleagues (Cheke et al., 2016), used the THT with food images, and thus it is possible that the relationship between episodic memory and BMI is specific to memory for food items. Previous studies, for example, Martin et al., (Martin et al., 2010), have shown that both lean and obese participants were able to better recall previously viewed images of animals (non-food) compared to food images, it would therefore be interesting to investigate if the relationship between BMI and episodic memory is also seen with non-food images in the THT.

The within-subject design of this study allowed me to investigate whether there were any differences in eating behaviours, cognitive or motivational factors between a fasted and fed state. My results revealed no significant differences in any of the eating behaviour, cognitive or motivational factors between being fasted or fed. The lack of effect in hedonic hunger and TFEQ disinhibition scores supports previous findings from Witt et al., (Witt et al., 2014) who found that a 4 hour fasting period had no effect on measures of TFEQ disinhibition score or hedonic hunger (PFS) score. However, a study which collected data from 808 male and female participants found mixed results when comparing the TFEQ scores to self-reported hunger levels (Yeomans and McCrickerd, 2017). Similar to my study, hunger in the study conducted by Yeomans and colleagues was measured using a 100mm VAS scale of “Please put a mark on the line to show how hungry you are right now, paying attention to the descriptions at the end of the line”, with the end-anchors “Not at all Hungry”, coded as zero, and “Extremely hungry”, coded as 100. In line with my results, they found that TFEQ restraint was independent of hunger rating. However, in contrast to the results of my study they found that TFEQ hunger and TFEQ disinhibition were influenced by hunger rating; TFEQ hunger and disinhibition were higher when hunger ratings were higher (Yeomans and McCrickerd, 2017). My results also found no differences between impulsivity scores between the fasted and fed sessions. Finally, given that the measures of impulsivity used in this study (BIS-11 scale and Stop Signal Task) are said to be measures of trait impulsivity (Guerrieri et al., 2007) it would be expected that this would not be affected by levels of current hunger.

This is the first study to my knowledge to investigate the relationship between episodic memory and current hunger state and the results of this study showed no effect of being

fasted or fed on the performance on the memory task. My results therefore suggest that hedonic hunger (measured by the PFS), TFEQ disinhibition, hunger and restraint, impulsivity (measured by both the BIS-11 and SRT) as well as episodic memory (measured by the THT) are all relatively stable constructs which are not considerably affected by daily variations in hunger. In addition, this may mean that whether a participant is hungry or full when completing these measures will not confound the research.

The strength of this study lies in its within-subject design, controlling for age, gender and IQ between the BMI groups. However, there are a number of limitations to the extent to which these findings can be generalised. This study did not use a controlled setting for fasted and fed sessions. Subjects were told to come into the department fasted (from breakfast). However, this does not mean that they had actually eaten before coming in for their testing session. While an attempt was made to confirm the level of hunger by measuring hunger ratings using a VAS scales, these are also self-reported and rely on the honesty of participants. Despite the significant difference between hunger VAS ratings within subjects, hunger ratings demonstrated significant overlap between conditions, with ratings ranging from 32-98 when fasted and 0-63 when in a fed state. Thus, future work should consider a controlled fasting session in the laboratory to confirm these findings. The applicability of the current findings may also be limited by the exclusive use of participants who were not currently dieting.

This chapter has shown that restraint, hedonic hunger and impulsivity may lead to higher levels of disinhibited eating behaviour and hedonic hunger may also lead to higher levels of hunger. This study was also able to replicate the findings of previous

literature suggesting that episodic memory is negatively associated with BMI (Cheke et al, 2016, Cheke et al, 2017). However, the previous chapter (Chapter 3) of this thesis discussed how dieting has been shown to be associated with changes in eating behaviours, for example, decreases in disinhibition and hunger and increases in restraint are associated with weight loss during both behavioural only and behavioural with very low calorie diet weight loss programme (Batra et al., 2013, Keranen et al., 2009, Teixeira et al., 2010, McGuire et al., 2001, Bryant et al., 2012, Pekkarinen et al., 1996, Foster et al., 1998) Given these associations between cognitive and motivational factors on disinhibited eating behaviour shown in this Chapter and the associations between eating behaviours and weight change in Chapter 3, it would therefore be interesting to investigate whether the relationships shown in this study are also found in individuals who are dieting and whether dieting has an effect on WWW memory in both lean and overweight individuals.

CHAPTER 5

THE EFFECTS OF DIETING ON EPISODIC MEMORY

Previous studies have shown that BMI is negatively associated with episodic memory (Cheke et al., 2016). However, the relationship between dieting and episodic memory, as measured by the Treasure-Hunt task is unknown. It also remains to be investigated whether the relationship between BMI and episodic memory (using the THT) is specific to images of food, and if there is an interaction with an individual's current dieting status. In order to answer these questions, I recruited 60 lean and overweight subjects (dieters and non-dieters) who were tested on one occasion. This study also explored whether the previously established relationship in Chapter 4 between cognitive/motivational factors and eating behaviours as well as BMI was also seen in a more heterogeneous group of participants including both dieters and non-dieters.

I found that there was a negative association between dieting and episodic memory in three of the THT subtasks. However, while the results showed a negative association between BMI and memory was replicated, there was no interaction between BMI and dieting status. My results also found that individuals in general had poorer performance on the "WWW" and "What" subtasks for food images compared to the same task with non-food images, and this effect did not interact with BMI or dieting status. Furthering the previous results in Chapter 4, I found that impulsivity, hedonic hunger and restraint were associated with TFEQ disinhibition scores. Overall, these results suggest that those

with higher BMI, and those on a diet have an impaired episodic memory, but that there is no interaction between these factors, and no impact of BMI or dieting on the effect of image type. The results extend previous findings that cognitive and motivational factors are important in explaining the variance in disinhibited, hunger and restrained eating behaviours. However, future work should investigate whether episodic memory changes with dieting using a within-subject longitudinal design as well as investigating the effect of specific diets on episodic memory performance.

5.1 Introduction

As previously mentioned in Chapter 3, it is widely known that eating behaviours change during dieting (French et al., 2012). However, it also seems that cognitive and motivational factors, such as memory, hedonic hunger are also affected by dieting. The previous chapter (Chapter 4) found that non-dieting individuals with greater impulsivity, specifically motor impulsiveness (BIS-11 motor subscale) and those with higher hedonic hunger, specifically when food is present (PFS present subscale), have more disinhibited eating behaviours (TFEQ disinhibition score). However, it remains to be determined if these relationships are still seen in a more heterogeneous sample of participants, including dieters. Previous studies have also shown a positive association between hedonic hunger and disinhibition (Lowe et al., 2009). However, hedonic hunger has been shown to be associated with dieting. In fact, hedonic hunger has been shown to decrease during a weight loss intervention (O'Neil et al., 2012). Thus, one might expect that hedonic hunger, as shown in Chapter 4 (PFS present scale) may also be seen to be associated with disinhibition in a group with more variance in hedonic hunger and there may also be an interaction with an individual's current dieting status. Previous studies

have shown that impulsivity is positively associated with disinhibition (Yeomans et al., 2008, Lyke and Spinella, 2004) similarly to my previous chapter results. However, given that the BIS-11 scale is said to be measures of trait impulsivity (Guerrieri et al., 2007), it would be expected that impulsivity will not interact with dieting status. Some researchers have also suggested a relationship between disinhibition and memory, in which individuals with high disinhibition have poorer retention or retrieval of food memory. This is because one study showed that individuals with high disinhibition were less likely to decrease their food intake as a result of memory enhancement compared to those with low disinhibition (Higgs et al., 2008). Furthermore, another study reported that dieters with higher disinhibition exhibit impairments in working memory that are related to preoccupying thoughts of food and body shape (Kemps and Tiggemann, 2005).

While eating behaviours are known to change during dieting, it seems that cognition and memory are also associated with dieting. One study investigating episodic memory (using a face-name paradigm) found significantly improved performance on this task after following a 6-month prescribed diet in 20 overweight women (Boraxbekk et al., 2015). Furthermore, a recent systematic review of 30 dietary interventions on human cognitive function showed that performance in working memory, visual-spatial and long-term verbal memory tasks diets were improved by decreases in dietary energy intake and fat intake, (Attuquayefio and Stevenson, 2015). This is consistent with studies carried out in animals, which have found that a high fat, refined sugar diet was associated with impaired hippocampal-dependent learning and memory, e.g. (Davidson et al., 2013, Jurdak and Kanarek, 2009, Molteni et al., 2002, Beilharz et al., 2014). In contrast to the idea that memory is improved by changes in dietary intake, one study

found an impaired performance on memory-based (spatial and digit span) tasks in those following a severe restriction of carbohydrates with an Atkins-like diet compared to those on a reduced calorie diet with macronutrient balance proportions (D'Anci et al., 2009). On the other hand, after finding no differences in performance in memory tasks between low- and high- carbohydrate diets, some have suggested that there is neither a positive or negative effect of dieting on cognition (Makris et al., 2013). Given these results suggest an unclear association between dieting and cognition (specifically memory), in this chapter I will investigate the relationship between dieting status and episodic memory using the Treasure Hunt Task (THT).

Although it remains to be shown whether or dieting is associated with episodic memory using the Treasure-Hunt task, the results of the previous chapter and previously published study (Cheke et al., 2016) have shown strong evidence that BMI is negatively associated with episodic memory (measured using the THT). However, these studies have all used food images in the THT and therefore this association may be specific to food images. A previous functional magnetic resonance imaging (fMRI) study has shown that both lean and obese participants were able to better recall previously viewed images of animals (non-food) compared to food images and found no interaction between BMI and image type (Martin et al., 2010). This chapter will investigate whether this negative association remains when using images of non-food in the THT task instead of food images.

5.2 Aims and Hypotheses

Aims	Hypotheses
Primary	
To investigate, between-subjects, the effects of dieting on episodic memory (measured using the THT), and whether this interacts with BMI.	It is predicted that overall individuals, regardless of their BMI, currently dieting are thinking more about what they eat and therefore have a better episodic memory for food than the control non-dieting group.
Secondary	
To investigate, using mixed within and between-subjects analysis, the association between BMI and episodic memory (using the THT) using images of neutral or food objects, and comparing performance on these two versions of the THT.	It is predicted that both lean and overweight individuals will have a better episodic memory score for non-food images compared to food images, and that there will be no interaction between BMI and image type.
To investigate the relationships between cognitive and motivational factors, as shown in the previous chapter, are affected by including dieters in the sample of participants.	It is predicted that impulsivity will not interact with dieting, but that the positive association between impulsivity and disinhibition will remain. There may be an interaction between hedonic hunger and dieting on the relationship with disinhibition, such that those who are not dieting and have higher hedonic hunger will have greater disinhibited eating.

5.3 Methods

Participants

I recruited 60 subjects (15 lean and currently dieting, 15 lean and not dieting, 15 overweight and currently dieting and 15 overweight not dieting) with an average age of 26.62 ± 5.56 years (39 females) through posters, flyers, online adverts, the Human Nutrition Research (HNR) unit database and word of mouth. Subjects were matched for gender across groups, but there were significant differences between groups in age, IQ, weight, and BMI (Table 5.1).

Individuals who expressed an interest in the study had an initial screening telephone call or they were emailed a form to fill out to ensure that they have no history of excessive drug or alcohol consumption (defined as >21 alcohol units per week for men and >14 units per week for women), no condition or disease such as hypo/hyperthyroidism, diabetes, cardiovascular disease or any mental health/psychiatric disorder (e.g. depression or anxiety). On the first visit, participants were asked to complete the EAT-26 questionnaire to ensure they had no current or previous eating disorder and were eligible to take part in the study if they scored ≤ 11 on the questionnaire (Garner et al., 1982). Pregnant or breastfeeding women or those who had previously undergone obesity surgery were excluded. Individuals with severe physical impairments affecting eyesight, hearing or motor performance were also excluded as this may have affected performance on the behavioural tasks. Individuals in the dieting group had to be currently enrolled and actively participating in a weight loss intervention, such as Slimming world, Weight Watchers or a personal diet and exercise regime.

Study design

The study was approved by the Department of Psychology Ethics committee. I invited eligible participants to attend the Department of Psychology in the centre of Cambridge on one occasion for approximately 2 hours. After arriving at the department, all participants gave written informed consent before taking part in the study. Participants then completed questionnaires and tasks, including the EAT-26 (full questionnaire can be found in Appendix 5), Three Factor Eating Questionnaire (TFEQ), Power of Food scale (PFS) questionnaire and the Barratt impulsive scale questionnaire (BIS-11), the Treasure hunt task, and Ravens advanced matrices IQ test in a random counterbalanced order. Participants were compensated £20 (plus travel expenses) for their time at the end of the visit.

Tasks and Questionnaires

Raven's Advanced Progressive Matrices

The set II of the Raven's advance progressive matrices was used as a measure of IQ (Raven and Lewis, 1962) as described in Chapter 4.

Three Factor Eating Questionnaire (TFEQ)

The TFEQ (Stunkard and Messick, 1985) was used to measure dietary restraint, disinhibition and hunger, as described in Chapter 3. The questionnaire can be found in Appendix 3.

Power of Food Scale (PFS)

The PFS (Lowe et al., 2009) was used to measure hedonic hunger, as described in Chapter 2. The questionnaire can be found in Appendix 2.

The Barratt Impulsiveness Scale (BIS-11)

The BIS-11 was used to measure impulsiveness (Patton et al., 1995). It is able to determine three second-order factors of impulsivity which include: motor impulsiveness, non-planning impulsiveness and attentional impulsiveness. The questionnaire can be found in Appendix 4.

The Treasure-Hunt Task

This version of the THT was slightly updated from the version used in Chapter 4. Each session of the task contained 5 phases, beginning with a single encoding phase, followed by four retrieval phases administered in a random order (what-where-when (WWW), what, where and when). Participants completed four full sessions of the Treasure Hunt task (two with food images e.g. apple, aubergine and two with non-food images e.g. pencil, calculator). Examples of the food and non-food images can be found in Appendix 7. Each trial of each task lasted 8 seconds. If participants did not finish a trial within 8 seconds a time-out symbol (stop sign) would appear briefly before the commencement of the next trial. If participants completed a trial in less than 8 seconds an icon would appear (a cross for the encoding, WWW and temporal tasks, the cursor changing colour in the object and location tasks) for the remaining time until the commencement of the next trial

The encoding phase (Figure 5.1a) consisted of four “hiding periods” in which participants would move 4 items around a complex scene (e.g., a beach, a desert) and “hide” them in locations of their choice. There were two scenes per session and each item was hidden twice within a given scene, across two hiding periods, labelled “day 1” and “day 2” and separated by a 2 second “night” scene. This resulted in a total of 16 item-location-time

combinations which overlapped in particular features but were each a unique combination.

The four retrieval phases consisted of What-Where-When (WWW) memory (Figure 5.1b), temporal memory (when; Figure 5.1c), location memory (where; Figure 5.1d) and object (what; Figure 5.1e) memory. The WWW memory phase involved participants moving each item they “hid” to the same location in the scene on that day. In the location memory phase, participants moved the cross to a location where they “had hidden something”. In the object memory phase, participants were presented with 24 items, 8 of which were the items participants had hidden during the encoding phase and 16 items were loosely matched for semantic and perceptual similarity. Participants moved a red square-shaped cursor to indicate which items they had previously hidden. In the temporal phase, participants were presented with four icons for each scene, numbered 1-4. An item appeared in the centre of the screen and participants were instructed to move the item to the appropriate scene icon to indicate the order in which they had hidden that item. Accuracy in the WWW and location tasks was assessed on how accurate the participant was between the item hid and item hid in the same place again, according to the distance. Accuracy in the temporal and object tasks was coded according to whether participants indicated the correct object or icon. I reprogrammed the task using Psychopy (Peirce, 2008) and created the new non-food images using Microsoft PowerPoint to prevent any copyright issues.

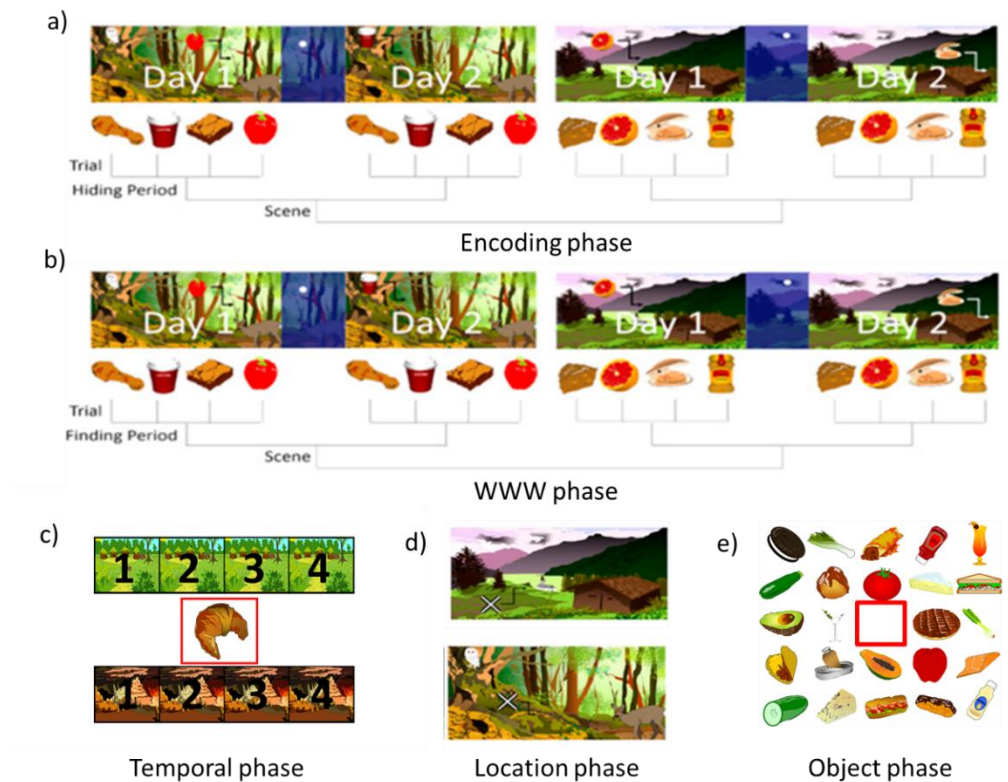


Figure 5.1: Treasure hunt task phases: a) Encoding phase; b) What-where-when (WWW) memory subtask; c) temporal (when) memory subtask; d) location (where) memory subtask; e) object (what) memory subtask. Adapted from Cheke et al., (Cheke et al., 2017).

Statistical Analysis

Comparison of differences of demographics, eating behaviours, impulsivity, IQ and memory between gender, age, BMI or dieting status were made using either Student's T test or Pearson's correlation analysis corrected for multiple comparisons using Sidak's correction method, when appropriate (Šidák, 1967). Pearson's correlation analysis (corrected for Sidak's correction for multiple comparisons) was also used to investigate relationships between eating behaviours, impulsivity, IQ and the memory subtasks.

Repeated measures analysis of variance (RMANOVA) models were used to investigate the effect of BMI, dieting status and image type (food vs. non-food images) on the

measures of memory, with dieting and BMI as a between subject factors and image type as a within subject factor. Further analysis was performed by adding an interaction term for BMI with dieting status, BMI and image type and dieting status with image type into the appropriate model.

Linear regression models were fitted to each of the measures of TFEQ eating behaviours to investigate the association between eating behaviours and measures of cognition (memory and impulsivity) and motivational factors (hedonic hunger), with the eating behaviour scores as the dependent variables in each model and all hedonic hunger, impulsivity and THT memory scores entered as independent variables. Two further linear regression models were fitted to BMI to investigate the association between BMI and eating behaviours, measures of cognition (memory and impulsivity) and motivational factors (hedonic hunger). In each model BMI was entered as the dependent model, with one model containing only the TFEQ eating behaviour scores as the independent variables and the other model with all TFEQ eating behaviour, hedonic hunger, impulsivity and THT memory scores entered as independent variables. The StepAIC function from the MASS package in R was used to select the best model fit by minimizing Akaike's information criterion (AIC) (Venables, 2002). Forward and backward model selections were implemented to allow for interactions between variables. To focus on cognitive and motivational factors as predictors of eating behaviours beyond the contribution attributable to gender, age, IQ, dieting status and BMI, these variables were adjusted for in all the regression models. Analyses were performed using the R statistical programme (R, 2008) (Version 3.1.2, R).

5.4 Results

Demographic associations

Many of the lean dieters reported that they were following a calorie restricted diet (9 out of 15) and the majority of the overweight dieting group reported that they were following a healthy food or macronutrient content changed diet, such as high protein or low carbohydrate (11 out of 15). In fact, of the 30 dieters, 1 reported to be on the slimming world weight loss intervention, 19 individuals reported a calorie restricted diet (3 of these reported also exercising and 4 reported combining with a low carbohydrate diet), 3 participants reported following a high protein diet (1 combining this diet with exercise) and 6 participants reported to be following a healthy eating diet (1 combining this diet with exercise).

Table 5.1: Participant demographics when grouped by BMI and dieting						
Variable	Mean (SD)					Group differences (F value) P-value ^a
	Lean dieting Group (BMI <24.5)	Lean non-dieting Group (BMI <24.5)	Overweight dieting Group (BMI >25.5)	Overweight non-dieting Group (BMI >25.5)	Overall	
Age (years)	23.53 (3.74)	23.93 (3.33)	28.20 (4.63)	30.80 (6.67)	26.62 (5.56)	(8.072) <0.001
Weight (kg)	64.48 (6.63)	65.83 (9.88)	115.61 (47.60)	82.89 (8.90)	82.20 (31.97)	(13.66) <0.001
BMI (kg/m²)	22.59 (1.49)	21.63 (1.45)	29.75 (5.15)	28.63 (3.41)	25.65 (4.81)	(24.03) <0.001
Gender (F:M)	13:2	9:6	8:7	9:6	39:21	($\chi^2=4.32$) 0.229
IQ score (/36)	24.73 (5.89)	28.93 (3.97)	22.07 (8.75)	22.13 (6.59)	24.47 (6.95)	(3.667) 0.018
a= one-way ANOVA; b=chi-squared test						

ANOVAs between the groups revealed significant differences between age, weight, BMI and IQ. Post-hoc t-tests showed that lean individuals were significantly younger than overweight individuals ($t(48)=-4.672$, $p<0.001$) and lean individuals also had a significantly higher IQ score on average compared to overweight individuals ($t(52)=2.783$, $p=0.007$).

There were no significant correlations between age and any of the eating behaviour or impulsivity scores. There was a significant correlation between age and the “When” part of the task (averaged for food and non-food images) with older participants having a poorer performance on this task compared to younger participants ($r=-0.296$, $p=0.022$). There were no other correlations with age and any of the other THT subtasks. As

expected, there was a significant difference in body weight between men and women ($t(29)=4.940$, $p=0.30$). There were no other differences between men and women in any demographic variables, eating behaviours and impulsivity or memory measures. There was a significant negative correlation between BMI and IQ ($r(58)=-0.383$, $p=0.003$). There was also a significant negative correlation between IQ and the TFEQ disinhibition score ($r(58)=-0.261$, $p=0.044$) and between IQ and the BIS11 non-planning subscale score ($r(58)=-0.361$, $p=0.005$). There were no other significant correlations between any of the eating behaviour, hedonic hunger or impulsivity scores and IQ. There was a significant positive correlation between IQ and all measures of memory ($df=58$, WWW: $r=0.621$, $p<0.001$, “What”: $r=0.444$, $p<0.001$ “Where”: $r=0.541$, $p<0.001$, “When”: $r=0.613$, $p<0.001$), as shown in Figure 5.2.

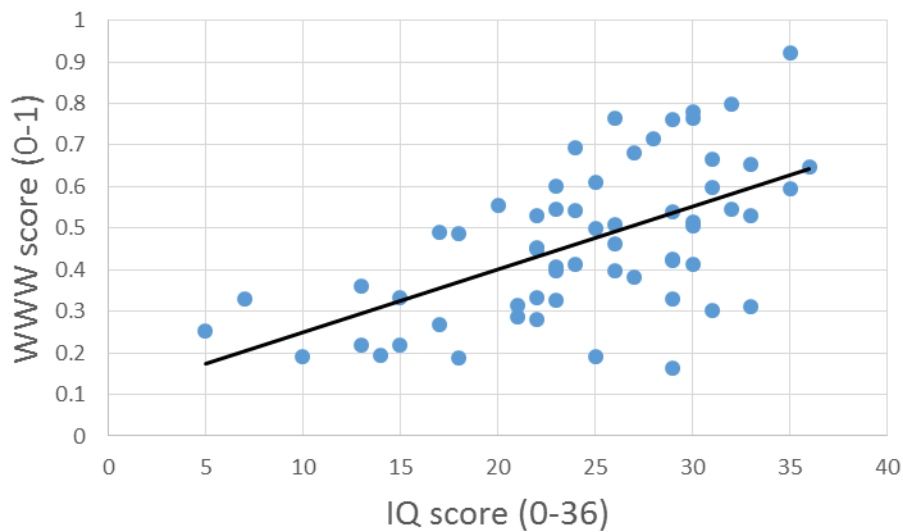


Figure 5.2: Correlation scatter plots for IQ and the WWW subtask score (averaged for food and non-food images).

Associations between eating behaviours, hedonic hunger and impulsivity
 Table 5.2 shows the relationship between each of the eating behaviour, hedonic hunger and impulsivity scores. Pearson’s correlation analysis corrected for Sidak’s multiple

comparisons (alpha adjusted to 0.0051) revealed a number of significant correlations between variables. A positive correlation was seen between TFEQ disinhibition and TFEQ hunger, BIS-11 total score and two of its subscales (attentional and non-planning) and the PFS total score and two of its subscales (available and present). TFEQ hunger was positively associated with the BIS-11 total score and the PFS total score and two of its subscales (available and tasted). As expected the PFS total score and its three subscales were all positively correlated with one another. The BIS-11 total score and its three subscales were also positively correlated with one another.

Table 5.2: Pearson's correlation matrix between eating behaviour and impulsivity variables

			TFEQ		BIS-11				Power of Food scale (PFS)			
			Restraint	Hunger	Total	Attentional	Motor	Non-planning	Total	Available	Tasted	Present
TFEQ	Disinhibition	Pearson Cor.	0.279	0.509	0.428	0.372	0.324	0.389	0.561	0.629	0.314	0.462
		Sig. (2-tailed)	0.031	<0.001	<0.001	0.003	0.012	0.002	<0.001	<0.001	0.014	<0.001
	Restraint	Pearson Cor.		-0.009	0.081	0.186	-0.015	0.053	0.022	0.109	-0.002	-0.007
		Sig. (2-tailed)		0.988	0.539	0.155	0.912	0.686	0.870	0.406	0.988	0.510
	Hunger	Pearson Cor.			0.360	0.335	0.325	0.268	0.491	0.482	0.390	0.359
		Sig. (2-tailed)			0.005	0.009	0.011	0.039	<0.001	<0.001	0.002	0.005
BIS-11	Total	Pearson Cor.				0.770	0.915	0.861	0.861	0.353	0.232	0.354
		Sig. (2-tailed)				<0.001	<0.001	<0.001	<0.001	0.006	0.074	0.006
	Attentional	Pearson Cor.					0.606	0.428	0.437	0.392	0.317	0.400
		Sig. (2-tailed)					<0.001	<0.001	<0.001	0.002	0.014	0.002
	Motor	Pearson Cor.						0.714	0.308	0.244	0.243	0.305
		Sig. (2-tailed)						<0.001	0.017	0.060	0.062	0.018
	Non-planning	Pearson Cor.							0.229	0.282	0.060	0.220
		Sig. (2-tailed)								0.029	0.650	0.092
PFS	Total	Pearson Cor.								0.873	0.822	0.861
		Sig. (2-tailed)								<0.001	<0.001	<0.001
	Available	Pearson Cor.									0.521	0.643
		Sig. (2-tailed)									<0.001	<0.001
	Tasted	Pearson Cor.										0.614
		Sig. (2-tailed)										<0.001

Interestingly, Pearson's correlation analysis corrected for multiple comparisons (alpha changed to 0.0047) revealed no significant associations between BMI and any of the eating behaviour, hedonic hunger or impulsivity scores. However, repeated measures ANOVA with overall group (taking into account BMI and dieting) as a between subject factor found a significant difference across groups in restraint scores ($F(3,1)=7.503$, $p<0.001$) with post-hoc t-tests revealing a significant difference between the dieting and non-dieting groups ($t(58)=3.344$, $p=0.001$). Those in the dieting group had higher restraint scores than the non-dieting group, as shown in Figure 5.3. There was also a significant interaction between BMI and dieting on the TFEQ restraint score ($F(1,1)=10.593$, $p=0.002$). Post-hoc t-tests revealed that lean dieters had significantly higher restraint scores than lean non-dieters ($t=5.588$, $p<0.001$), overweight dieters ($t=2.445$, $p=0.021$) and overweight non-dieters ($t=2.691$, $p=0.012$). There were no other significant interactions between BMI and dieting on any of the eating behaviour, hedonic hunger or impulsivity scores, as shown in Table 5.3.

Table 5.3: Eating behaviour and impulsivity scores when grouped by BMI and dieting

Variable	Mean (SD)				Group differences (F value) P-value ^a
	Lean dieting Group (BMI <24.5)	Lean non-dieting Group (BMI <24.5)	Overweight dieting Group (BMI >25.5)	Overweight non-dieting Group (BMI >25.5)	
TFEQ disinhibition	7.40 (3.83)	5.60 (2.85)	7.73 (3.53)	8.27 (4.48)	(1.449) 0.238
TFEQ restraint	12.53 (3.54)	5.60 (3.25)	8.93 (4.46)	8.47 (4.66)	(7.503) <0.001
TFEQ Hunger	6.13 (2.50)	5.80 (3.47)	6.73 (3.59)	6.40 (2.59)	(0.249) 0.862
PFS total	2.91 (0.73)	2.86 (0.78)	2.65 (0.84)	2.95 (1.01)	(0.376) 0.771
PFS available	2.65 (0.98)	2.50 (1.07)	2.26 (0.74)	2.41 (1.11)	(0.427) 0.735
PFS tasted	2.89 (0.71)	3.01 (0.88)	2.68 (1.12)	3.23 (1.04)	(0.876) 0.463
PFS present	3.28 (0.88)	3.22 (0.96)	3.20 (1.20)	3.42(1.12)	(0.133) 0.940
BIS11 total	66.40 (10.80)	57.67 (10.94)	62.33 (13.45)	62.07 (13.77)	(1.259) 0.297
BIS11 non-planning	24.40 (5.64)	20.80 (4.48)	21.87 (4.22)	23.87 (6.24)	(1.574) 0.206
BIS11 motor	24.67 (4.45)	22.13 (3.85)	23.80 (5.86)	22.67 (5.60)	(0.773) 0.514
BIS11 attentional	17.33 (3.70)	14.73 (3.79)	16.67 (4.95)	15.53 (4.49)	(1.108) 0.353
a= one-way ANOVA, differences between groups					

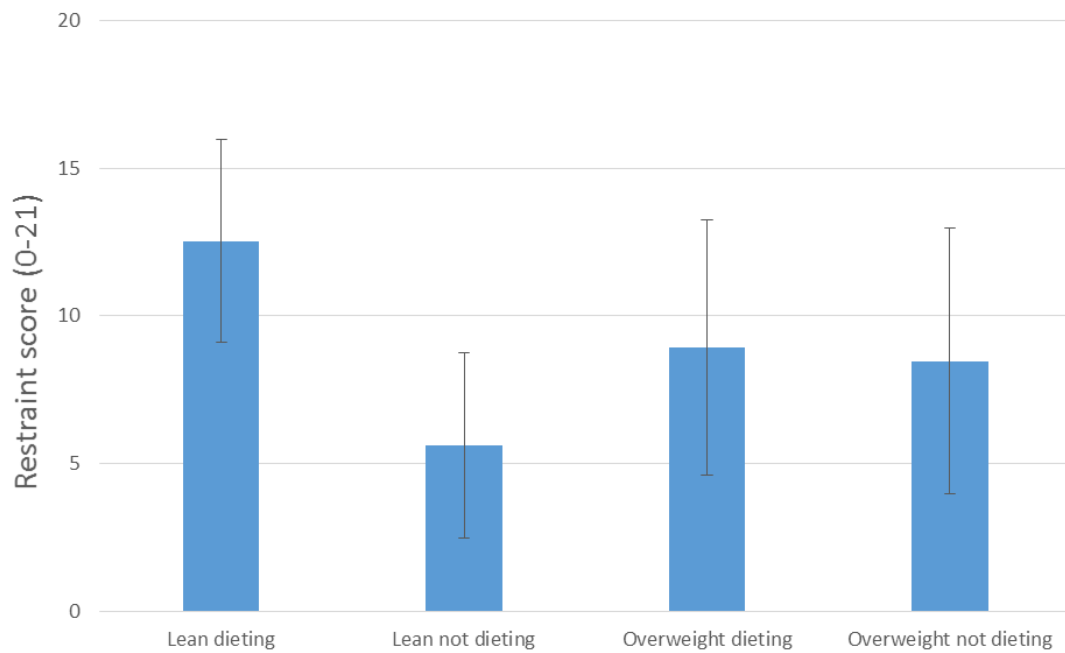


Figure 5.3: Levels of dietary restraint across BMI and dieting groups

The relationship between dieting, BMI and episodic memory

To assess the relationship between dieting and episodic memory and whether BMI and dieting status interact on their relationship with memory, a RMANOVA was conducted with BMI and dieting as between subject factors, controlled for age, dieting status, gender and IQ. There was a significant main effect of dieting on the “WWW”, “What” and “Where” subtasks (“WWW”: $F(1,1)=6.577$, $p=0.011$, “What”: $F(1,1)=7.824$, $p=0.006$, “Where”: $F(1,1)=4.858$, $p=0.029$), but not on the “When” subtask ($F(1,1)=0.015$, $p=0.903$), as shown in Figure 5.4. There was also a significant main effect of BMI on performance of “WWW”, “Where” and “When” memory subtasks (“WWW”: $F(1,1)=6.190$, $p=0.014$, “Where”: $F(1,1)=5.742$, $p=0.018$, “When” : $F(1,1)=5.064$, $p=0.026$), but no significant effect of BMI on the “What” subtask ($F(1,1)=2.571$, $p=0.110$). Furthermore, there was no interaction between BMI and dieting on any of the tasks

(“WWW”: $F(1,1)=0.025$, $p=0.875$, “What”: $F(1,1)=1.886$, $p=0.171$, “Where”: $F(1,1)=1.104$, $p=0.294$, “When”: $F(1,1)=0.535$, $p=0.465$).

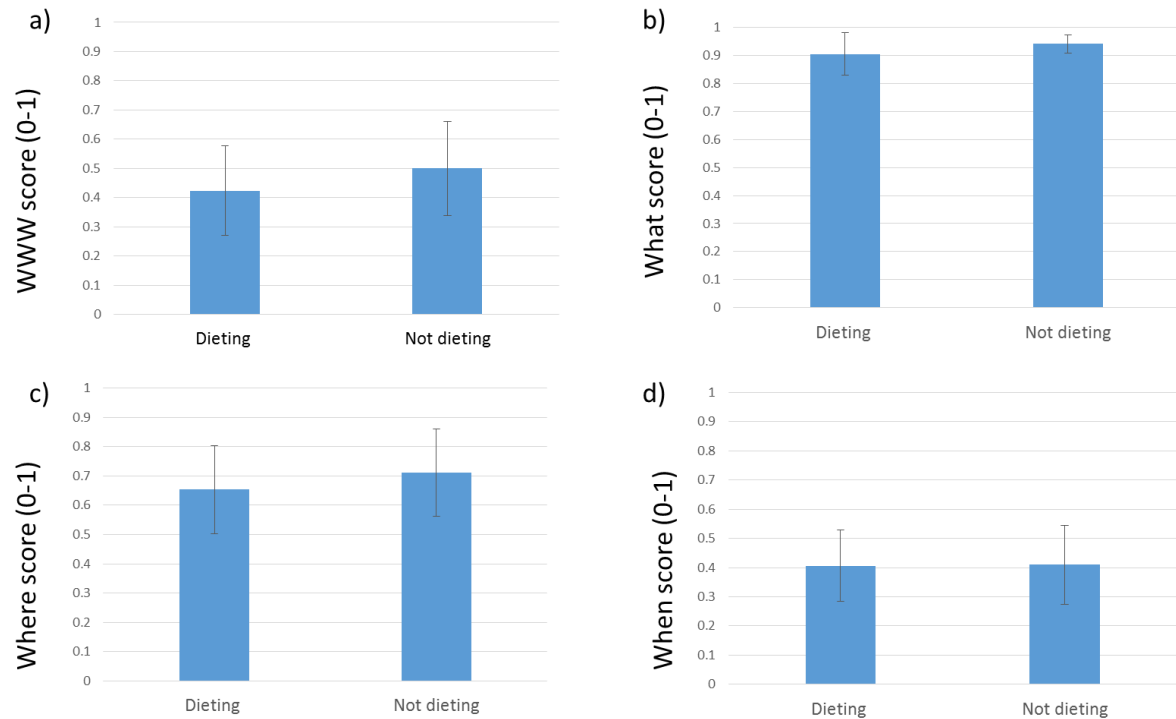


Figure 5.4: Bar charts to show the mean and standard deviations between dieting and non-dieting groups in the memory subtasks for a) “WWW”, b) “What”, c) “Where” and d) “When”.

The effect of image type on episodic memory

In order to investigate whether there was an effect of image type (food images vs. non-food images) on the association between BMI and THT memory performance, a RMANOVA was run with image type as a within subject factor and BMI as a between subject factor, controlled for age, dieting status, gender and IQ. Again, there was a significant main effect of BMI in the “WWW”, “where” and “when” subtasks, suggesting poorer performance in those with higher BMI (“WWW”: $F(1,1)=6.130$, $p=0.014$, “Where”: $F(1,1)=5.694$, $p=0.018$, “When”: $F(1,1)=5.105$, $p=0.025$), but not for the “what” subtask ($F(1,1)=2.497$, $p=0.115$). There was a significant main effect of image type on memory performance for the “WWW” and “what” subtasks (“WWW”: $F(1,1)=15.769$,

$p < 0.001$, “What”: $F(1,1)=9.510$, $p=0.002$), but not for the “where” and “when” subtasks (“Where”: $F(1,1)=3.098$, $p=0.080$, “When”: $F(1,1)=0.622$, $p=0.431$), as shown in Figure 5.5. Individuals overall performed better in the “WWW” and “what” with the non-food images compared to the same subtask with food images. However, there was no interaction between BMI and image type on any of the memory subtasks (“WWW”: $F(1,1)=0.038$, $p=0.846$, “What”: $F(1,1)=0.161$, $p=0.689$, “Where”: $F(1,1)=0.001$, $p=0.976$, “When”: $F(1,1)=1.642$, $p=0.201$).

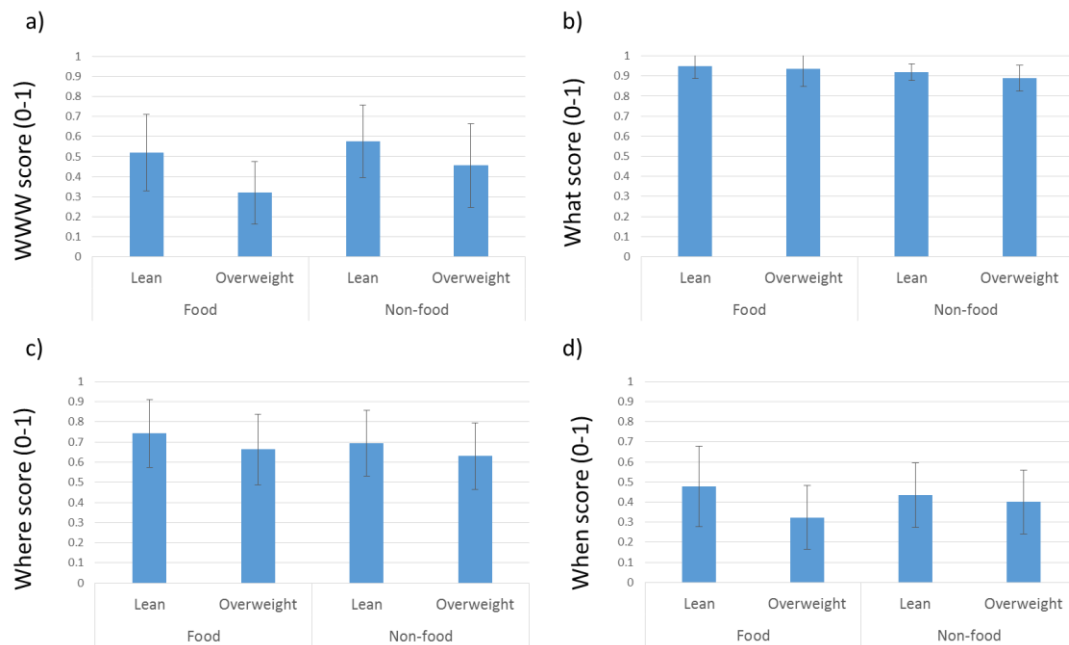


Figure 5.5: Bar charts for the mean and standard deviations for memory subtasks for a) “WWW”, b) “what”, c) “where” and d) “when” for food vs non-food tasks between groups.

In order to investigate the association between dieting and image type (food images vs. non-food images) on episodic memory, a RMANOVA was run with image type as a within subject factor and dieting as a between subject factor, controlled for age, dieting status, gender and IQ. There was a significant main effect of dieting on memory performance for the “WWW”, “what” and “where” subtasks (“WWW”: $F(1,1)=7.985$, $p=0.005$,

“What”: $F(1,1)=8.705$, $p=0.004$, “Where”: $F(1,1)=6.021$, $p=0.015$), but not for the “when” subtask ($F(1,1)=0.015$, $p=0.901$). Those in the non-dieting group performed better in the “WWW”, “what” and “where” subtasks compared to those in the dieting group. There was also a significant main effect of image type in the “WWW” and “what” subtasks (WWW: $F(1,1)=15.979$, $p<0.001$, “What”: $F(1,1)=9.759$, $p=0.002$), but not for the “where” or “when” subtasks (“Where”: $F(1,1)=3.128$, $p=0.078$, “When”: $F(1,1)=0.619$, $p=0.432$). Again, individuals performed better in the “WWW” and “what” with the non-food images compared to the same subtask with food images. However, there was no interaction between dieting status and image type on any of the memory measures (“WWW”: ($F(1,1)=0.203$, $p=0.653$, “What”: $F(1,1)=0.271$, $p=0.603$, “Where”: $F(1,1)=0.529$, $p=0.468$, “When”: $F(1,1)=0.619$, $p=0.432$).

Replicating the relationship between BMI and episodic memory for food

In order to replicate the association between BMI and THT memory performance with food images as previously described in Chapter 4, a RMANVOVA was run with BMI as a between subject factor and using only the results from the food image memory tasks, controlled for age, dieting status, gender and IQ. There was a significant main effect of BMI on THT memory performance for the “WWW”, “where” and “when” subtasks, suggesting poorer performance in those with higher BMI (“WWW”: ($F(1)=21.527$, $p<0.001$, “Where”: $F(1)=4.096$, $p=0.045$, “When”: $F(1)=20.278$, $p<0.001$), but not for the “what” subtask ($F(1)=0.209$, $p=0.649$; Figure 5.6).

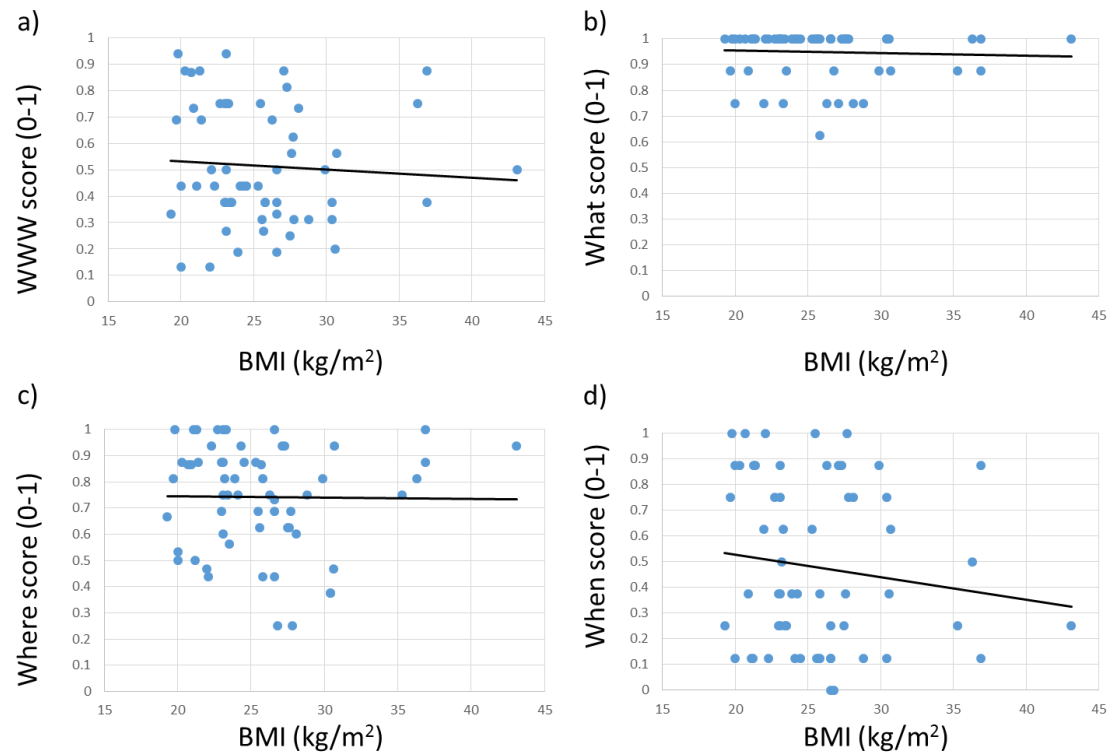


Figure 5.6: Correlation scatter plots between BMI and the memory subtasks for a) “WWW”, b) “What”, c) “Where” and d) “When”.

Association between eating behaviours, cognition and motivational factors

To investigate the nature of the relationship between BMI, eating behaviours and cognitive and motivational factors, four linear regression analyses were conducted. In models 1-3, the extent to which eating behaviours are predicted by cognitive and motivational factors was assessed with TFEQ scores as the dependant variables in each model and all cognitive (impulsivity and memory) scores and motivational (hedonic hunger) scores as independent variables.

Model 4 assessed the extent in which the TFEQ eating behaviours predicted BMI, with BMI entered as the dependent variable and all TFEQ eating behaviour scores entered as independent variables. Model 5 assessed the extent in which the association between eating behaviours and BMI may be explained by cognitive and motivational factors: BMI

was the dependent variable and all eating behaviour, cognitive and motivational factors were independent variables with interactions between eating behaviour scores and cognitive/motivational factors also entered into the model. To all best-fit models from the stepAIC selection process were adjusted for age, dieting status, gender and IQ.

Table 5.4: Regression analysis models for eating behaviours and BMI.						
Model	R²	Adj. R²	Predictors	β (SE)	T-value	P-value
Model 1: Disinhibition	0.63	0.53	TFEQ hunger	0.259 (0.14)	1.821	0.075
			TFEQ restraint	0.214 (0.09)	2.349	0.023
			PFS total	1.711 (0.52)	3.314	0.002
			BIS-11 total	0.052 (0.03)	1.557	0.126
			WWW*	6.971 (3.06)	2.279	0.027
			Where*	-4.762 (2.96)	-1.612	0.114
Model 2: Restraint	0.43	0.32	PFS total	-1.038 (0.78)	-1.320	0.193
			TFEQ disinhibition	0.375 (0.18)	1.997	0.051
			What*	9.471 (6.50)	1.456	0.152
Model 3: Hunger	0.40	0.28	TFEQ disinhibition	0.280 (0.13)	2.222	0.031
			PFS total	1.191 (0.52)	2.276	0.027
			WWW*	-3.299 (2.31)	-1.426	0.160
Model 4: BMI (with TFEQ scores only)	0.25	0.18	TFEQ disinhibition	0.030 (0.16)	1.915	0.060
Model 4: BMI	0.61	0.56	When*	-4.704 (3.15)	-1.493	0.142
All models were controlled for age, dieting status, gender, and IQ						
*=THT with food images only						

As shown in table 5.4, in model 1, variance in disinhibition score was best fit by a model containing the TFEQ hunger, TFEQ restraint, PFS total, BIS-11 total, “WWW” and “where” THT subtask scores (food images only) predicted 63% of the variance in TFEQ disinhibition score. The TFEQ restraint, PFS total and “WWW” THT scores were positively associated with the TFEQ disinhibition score. However, there was only a trend towards a positive association between TFEQ hunger and TFEQ disinhibition and no association between the BIS-11 total and “where” THT subtask scores with TFEQ disinhibition score.

In model 2, the best fit model for the TFEQ restraint model contained the TFEQ disinhibition, PFS total and the “what” THT subtask score, and predicted 43% of the variance in TFEQ restraint score. The TFEQ disinhibition had a trend towards a positive association with TFEQ restraint score, whereas the PFS total and “where” THT subtask scores were not associated with the TFEQ restraint score. In model 3, the best fit model for variance in TFEQ hunger score contained the TFEQ disinhibition, hedonic hunger and “WWW” THT score and predicted 40% variance in TFEQ hunger score. In contrast to the TFEQ disinhibition model, this model gave a positive association between TFEQ disinhibition and TFEQ hunger score. Model 4, which had BMI as the dependent variable, was best fit by only the TFEQ disinhibition score and predicted 25% of the variance in BMI. However, there was only a trend towards a positive association between TFEQ disinhibition and BMI. Finally, in model 5, which had BMI as the dependent variable, a best-fit model contained only the “When” THT subtask score, which predicted 61% variance in BMI. However, this relationship between BMI and the “When” THT subtask score was not significantly associated.

5.5 Discussion

The primary aim of this study was to investigate, between-subjects, the effect of dieting on episodic memory in both lean and overweight participants. The results of this chapter suggest that those on a diet, regardless of their BMI, have an impaired performance on the THT compared to those currently not on diet. This is the first study to my knowledge to find an impaired performance in an episodic memory task in individuals dieting, compared to non-dieters. This could be explained by dieters being preoccupied with dieting-related thoughts, for example, thoughts related to planning and managing their hunger and eating as well as worrying about food, weight and body shape. Thus, cognitive resources available for performing non-dieting tasks are depleted (Green and Rogers, 1998; Green, 1995) and in turn could explain the dieter's poorer cognitive performance on the THT compared to non-dieters. While a previous study showed that performance on a face-name paradigm episodic memory task was significantly improved after 6 months on both a modified Palaeolithic-type diet and a Nordic Nutritional Recommended diet in postmenopausal women (Boraxbekk et al., 2015). My study was unable to control for the length of time an individual was dieting for or why they were dieting. Thus, it could be that those who go on a diet have a worse memory on average, as shown in this study, however, dieting for long periods improve the episodic memory. A recent systematic review of 30 different diet interventions, suggests that overall diets which decreased energy intake or decreased dietary fat content, were beneficial to performance in working memory, visual-spatial and long-term verbal memory tasks (Attuquayefio and Stevenson, 2015). However, one study found that those on a severe restriction of carbohydrates, with an Atkins-like diet after just one week performed worse on memory-based (spatial and digit span) tasks

compared to those on a reduced calorie diet with macronutrient balance proportions (D'Anci et al., 2009). while other studies have found no

association between dieting and performance in memory tasks (Stroop Task, Continuous Performance Task, Word Recall and Wisconsin Card Sorting Task), e.g. (Makris et al., 2013). Although this study seems to propose that dieting has a negative effect on episodic memory, previous studies suggest that the relationship between dieting and cognition, specifically memory, is unclear. Therefore, further research is required to fully understand the effect dieting has on episodic memory over longer periods of time.

While the effect of dieting on episodic memory remains to be further investigated, this study was able to replicate the negative relationship between BMI and episodic memory. My results showed that participants with a higher BMI (regardless of dieting status) had a poorer performance on the “WWW”, “Where” and “When” (but not “What”) subtasks with food images. As seen in Figure 5.5, the “what” task showed a ceiling effect in the scores, which may explain the lack of association between this subtask and BMI. The negative association with BMI and the “WWW”, “where” and “when” subtasks, supports the previous chapter results and the results published by Cheke and colleagues (Cheke et al., 2016), which also found that those with higher BMI had an impaired performance on all measures of the THT including spatial, temporal and item memory, as well as the ability to combine these elements (“What-Where-When” memory). Thus, these results provide strong evidence that individuals with a higher BMI have an impaired episodic memory for food images.

Since a main effect of both dieting status and BMI was seen on episodic memory performance (using the THT), it would be anticipated that overweight dieters would

have a poorer performance in comparison to lean dieters/non-dieters or overweight non-dieters. However, my results found no interaction of BMI and dieting status on the THT performance. This suggests that the individual associations between memory and dieting and BMI are not explainable by a potential increased likelihood of individuals with higher BMI to be on a diet, or for dieting individuals to be overweight. However, the data is difficult to interpret due to the large variety of diets that the dieting group reported to be following, and how this varied across BMI groups. In fact, in the lean group most dieters reported that they were following a calorie restricted diet whereas the majority of the overweight group reported that they were following a healthy food or macronutrient content changed diet, such as high protein or low carbohydrate. Given these differences in the type of diet, and the potentially different impacts of different diets on memory (D'Anci et al., 2009), future research focussing on a more homogenous group of dieters may be useful to tease out whether there are individual differences in episodic memory whilst following the same diet. To fully understand the association between BMI, dieting and episodic memory, future studies may also consider a large enough sample compare different types of diet, for example, diets such as a calorie restricted diet only, combined calorie restriction and exercise or a combined calorie restriction with cognitive behavioural therapy. This would help to understand whether it was a specific type of diet that influences episodic memory, and how this may interact with BMI.

Another aim of this study was to investigate the association between BMI and episodic memory (using the THT) using images of neutral or food objects, and comparing performance on these two versions of the THT. As mentioned in Chapter 4, the THT was previously developed using only use food images, and therefore the relationships seen,

in Cheke et al., (Cheke, 2016) and Chapter 4, between episodic memory and BMI may be specific to memory for food items. My results found that overall, regardless of BMI or dieting status, participants had a poorer performance on the “WWW” and “what” subtasks of the THT when food images were used compared to the same tasks with the non-food images. This suggests that participants have a poorer episodic memory for food images compared to non-food images, specifically when recalling the image (“what” subtask) and when integrating all information of what, where and when of the image (“WWW” subtask). These results support a previous study which found that both lean and obese participants were able to better recall non-food compared to food images (Martin et al., 2010). Also in line with the results from Martin and colleagues, I found no interactions between BMI and image type on the relationship with episodic memory. The results presented in this chapter also found no interaction between dieting status and image type on the relationship with episodic memory. These results suggest that the negative association between memory and BMI and dieting status are not specific to food images, but that people in general find food images harder to remember. Further research is required to fully understand the impairment in episodic memory with food images compared to non-food images.

This study also aimed to replicate the relationship between eating behaviours and motivation/ cognition, as shown in the previous chapter, in a more diverse group of participants and larger sample size than in Chapter 4. This study therefore investigated the effect of cognitive and motivational factors on eating behaviours in a group of dieters and non-dieters. As in the previous chapter, my results found a positive association between restrained and disinhibited eating behaviours. As mentioned previously this could be explained by previous studies which have suggested that in lean

individuals, greater restraint acts as a risk factor for overeating, whereas in overweight individuals greater restraint may protect against overeating, as the relationship between disinhibition and weight is weakened in individuals with high restraint (Hays et al., 2002, Williamson et al., 1995, Hays and Roberts, 2008, Dykes et al., 2004)

My results also found a positive association between disinhibited eating behaviour and hedonic hunger. This also replicated results from Chapter 4 and, as mentioned previously, this supports previous results which showed a positive association between hedonic hunger and disinhibition (Lowe et al., 2009).

My results also found that those who scored higher on the overall “WWW” task (for food images only) reported higher TFEQ disinhibition scores, suggesting that those who had an overall better episodic memory are more likely to experience disinhibited eating behaviours, regardless of BMI or dieting status. This result contrasts to previous evidence suggesting that individuals with higher disinhibition were less likely to decrease their food intake as a result of memory enhancement compared to those with low disinhibition, which was suggested that this may be because individuals with high disinhibition have poorer retention or retrieval of food memory (Higgs et al., 2008). Furthermore, another study reported that dieters with higher disinhibition exhibit impairments in working memory that are related to preoccupying thoughts of food and body shape (Kemps and Tiggemann, 2005). These results therefore suggest that regardless of age, gender, BMI, IQ and dieting status, restraint, hedonic hunger and episodic memory are important factors in predicting disinhibited eating behaviour. However, given my results do not support the observations of others, further work is

required to understand the direction and nature of this association and whether this may be explained by the nature of the task used to measure episodic memory.

My results also showed that hedonic hunger was positively associated with TFEQ hunger scores. This positive relationship between PFS total score and TFEQ hunger score supports the results of the previous chapter, suggesting that those with higher hedonic hunger scores, regardless of dieting status, had higher levels of reported hunger. This result supports the findings from a previous study which also found a positive association between hedonic hunger and TFEQ hunger (Lowe et al., 2009). These results therefore suggest that regardless of dieting status, age, gender, BMI and IQ, that hedonic hunger may be important in predicting self-reported hunger scores.

The results of this study also found a trend towards a positive association between BMI and disinhibited eating (TFEQ disinhibition score). This suggests that those with higher disinhibited eating, regardless of dieting status, had a higher BMI. This positive relationship between BMI and disinhibition has replicated the results from the previous Chapter as well as being in line with the results from many previous studies, as discussed in Chapters 1 and 4 (Chaput et al., 2009, Gallant et al., 2010, Hainer et al., 2006, Schubert and Randler, 2008, Hays and Roberts, 2008, Hays et al., 2002, Provencher et al., 2007, Bellisle et al., 2004). Thus, it seems that disinhibition is an important factor in predicting BMI. However, once cognitive and motivational factors were added into the model this trend was no longer seen. This may be explained by an interactive effect of cognitive and motivational factors with disinhibition causing the relationship between disinhibition and BMI to be weakened.

Notably, this study also found a significant difference in TFEQ restraint scores between groups (lean dieters, lean non-dieters, overweight dieters and overweight non-dieters). On average the lean participants in this study reported higher levels of restraint compared to the overweight participants. This is in line with a body of evidence which suggests a negative association between BMI and restraint, e.g. (Hainer et al., 2006, Provencher et al., 2003, Williamson et al., 1995, Boschi et al., 2001). My results also suggest that those currently dieting (lean and overweight) reported higher restraint scores than the non-dieting group. This is also in line with a body of evidence (previously discussed in Chapter 3) from weight loss intervention studies which found that restraint increased after following weight loss interventions, e.g. (Levine et al., 2007, Karhunen et al., 2012, Dalen et al., 2010, Frestedt et al., 2012, Kiernan et al., 2001, Wadden et al., 2004, Westerterp-Plantenga et al., 1998, Clark et al., 1994). Interestingly, my results also found an interactive effect of BMI and dieting on restraint score. These results suggest that dieting is positively associated with restraint scores in lean, but not overweight individuals. Unlike the lean group, the results from the overweight groups suggest that restraint score and dieting are not synonymous: one can be following a diet without demonstrating higher restraint. Although in Chapter 3 it was suggested that weight loss interventions that increase restraint may be useful behavioural strategies to achieve longer term weight maintenance, my results suggest that associations between weight-loss strategies and restrained eating behaviour may vary across individuals of different BMIs. Alternatively, as mentioned above, it is possible that the differences in the association between dieting and restraint in lean and overweight individuals may have stemmed from the type of diets individuals were following. Given that lean individuals were more likely to be following a calorie-restriction diet, it is possible that this form of

diet is more associated with increased restraint than other forms of diet, for example, Foster et al., found that a very low calorie diet was associated with significant increases in restraint (Foster et al., 1998).

This study benefitted from a within-subject design allowing the assessment of differences in episodic memory for food and non-food images. Unlike the previous chapter this study also included a more heterogeneous group of individuals, including dieters to investigate the effect of dieting in both lean and overweight individuals. However, the extent to which these findings can be generalised is limited by several factors. The dieters used in this study self-reported the diet they were following and as such this relied on the honesty of participants. I also did not collect any information regarding how much weight the dieting group had lost on their diet nor how long they had been following their diet for. As reported above, there were differences in the diets being followed between BMI groups and there were a few different diets reported. While several studies have shown that being on a diet has been associated with improved memory (Attuquayefio and Stevenson, 2015), it is possible that individuals who initially choose to go on a diet may have a poorer episodic memory, but once they have been on the diet for some time this episodic memory improves. Therefore, future research may benefit from investigating whether episodic memory changes with dieting using a within-subject design by measuring episodic memory at baseline before asking participants to follow a diet. It would also be interesting to see if specific diets had variable effects on episodic memory by using a randomised controlled study design to randomise individuals to a different weight loss interventions or no weight loss intervention (control group).

The results presented in this chapter provide evidence that individuals on a diet demonstrate poorer episodic memory ability compared with those not on a diet. Given the relationships seen in this study and the limitations of this study which include using self-reported dieters, future work should investigate whether episodic memory changes with dieting using a within-subject longitudinal design. Future studies should also consider investigating the effect of specific diets on episodic memory performance.

CHAPTER 6

GENERAL DISCUSSION OF THESIS

The overall objective of this thesis was to evaluate individual differences in eating behaviours and investigate their relationship with motivation, cognition and weight control. The more specific aims of this thesis were to a) investigate the relationship between eating behaviours or hedonic hunger and total energy intake, as well as energy intake from healthy/unhealthy foods and low/high energy dense foods; b) to examine whether baseline scores and changes in eating behaviour scores are associated with changes in weight during a weight loss and weight maintenance period as well as whether eating behaviours are able to predict changes in weight during these periods; c) to test if motivational (hedonic hunger and hunger status) and cognitive (impulsivity and episodic memory) factors have an influence on eating behaviours; d) to investigate between-subjects the effects of dieting on episodic memory and whether the relationships between cognitive and motivational factors with eating behaviours were affected by including dieters.

I will first discuss whether this thesis has answered these objectives by evaluating each study in the order they are reported and suggesting an overall model for my thesis results (6.1 Overview of results). Next I will move onto to discuss the strengths and limitations of the thesis (6.2 Strengths and Limitations) as well as suggesting applications that the results of this thesis has for weight control (6.3 Applications for weight control) before summarizing my thesis with some concluding remarks (6.4 Final remarks).

6.1 Overview of results

In the first study of this thesis, which was reported in Chapter 2, the aim was to investigate the relationship (and any interactions) between hedonic hunger, restraint and disinhibition with overall food consumption, consumption of perceived healthy or unhealthy foods and consumption of low or high energy density foods. Whilst it was predicted that those with higher disinhibition and hedonic hunger or those with lower restraint would consume more total calories from the ad-libitum buffet, this study only found that lower restraint was associated with higher total calories consumed during the ad-libitum buffet. In short, my results suggested that low restraint may lead to higher intake of food. This first study also showed that lower restraint was also associated with higher intake of unhealthy foods, but restraint was not associated with consumption of healthy foods during the ad-libitum buffet. Despite the overall unclear relationship from previous literature (Contento et al., 2005, De Castro, 1995, Tuschl et al., 1990a, French et al., 1994, Cavanagh and Forestell, 2013), it was predicted that restraint would be associated with healthy and unhealthy food consumption, with restraint being positively associated with healthy food consumption and negatively associated with unhealthful food consumption. However, this chapter only suggests that regardless of BMI, individuals with lower restrained eating behaviour may be a factor in the consumption of perceived unhealthy foods. Using previous literature (Contento et al., 2005, Lahteenmaki and Tuorila, 1995), it was predicted that disinhibition would be negatively associated with healthy food consumption and positively associated with unhealthy food consumption in the buffet meal. However, my results revealed no relationship between disinhibition and healthy or unhealthy food consumption.

A further finding of study 1 was that lower restraint was also associated with consumption of both high and low energy density foods. It was predicted that there would be a positive association between restraint and low energy density food consumption and a negative association between restraint and high energy density food consumption due to a previous study which showed that restrained eaters ate more cookies in a taste test when labelled as low-calorie compared to a high-calorie label (Cavanagh and Forestell, 2013) and another study which showed that restrained eaters reported less calorie dense food items during a 7-day food diary (Laessle et al., 1989a). However, my results from this study suggest that restraint does not help distinguish between foods of high or low energy density but that this may be explained by the lack of labelling of calories on the foods.

This first chapter of my thesis could help answer one of the aims of this thesis which was to investigate the relationship between motivation and eating behaviours with weight control. However, this study investigated weight control by means of food intake using a cross-sectional design. To answer this aim of my thesis it was necessary to investigate weight control in a longitudinal setting. I decided that the “Diet Obesity and Genes” (DiOGenes) study, carried out between 2005 and 2010 in eight European countries, would allow me to investigate this relationship.

The second study, which was described in Chapter 3, examined whether both baseline scores and changes in eating behaviour scores were associated with changes in weight during an 8-week low-calorie diet and during a 6-month weight maintenance period. This data was collected from the “DioGenes” study carried out in eight European countries (Netherlands, Denmark, UK, Greece, Germany, Spain, Bulgaria and Czech

Republic) and allowed me to investigate the relationship between eating behaviours and changes in weight. It was hypothesised that lower baseline restraint (but not disinhibition or hunger) would be associated with greater weight loss during the 8-week low-calorie diet, because only one study found a modest relationship between low baseline restraint scores and greater weight loss during a very-low energy diet with behavioural counselling intervention (Foster et al., 1998). However, the majority of previous studies using low-energy liquid diets showed no association between baseline dietary restraint, disinhibition and hunger with weight loss (Vogels et al., 2005, Vogels and Westerterp-Plantenga, 2007, Westerterp-Plantenga et al., 1998, Clark et al., 1994, LaPorte and Stunkard, 1990, Pekkarinen et al., 1996). Similarly to Foster et al., (Foster et al., 1998), my results also found that lower restraint (but not disinhibition or hunger) at baseline predicted greater weight loss during the 8-week low-calorie diet, suggesting that people with low dietary restraint appear to benefit from weight loss on liquid formula diets. However, future work is required to test this theory experimentally. This study also aimed to examine the relationship between post-low-calorie diet eating behaviour scores and weight change during the weight maintenance period. Despite predicting that higher restraint and lower disinhibition and hunger scores after the low-calorie diet would predict less weight re-gain during the 6-month weight maintenance period, no associations were seen between post-low-calorie diet eating behaviour scores and weight change during the weight maintenance period.

Despite the association between baseline restraint and changes in weight during the low-calorie diet, there was no association between changes in eating behaviours and changes in weight during the same period. I predicted that increases in restraint and decreases in disinhibition (but not hunger) would be associated with greater decreases

in weight during the weight loss intervention. This hypothesis arose from several studies which had previously shown this result (Batra et al., 2013, Bryant et al., 2012, Teixeira et al., 2010, McGuire et al., 2001, Pekkarinen et al., 1996, Foster et al., 1998, Keranen et al., 2009). However, the results from my study suggest that eating behaviour change does not influence changes in weight during a low-energy liquid diet. This could be because food choice has been removed during the weight loss intervention as this study used a prescribed liquid formula diet. As such, individuals needed to adhere to the prescribed diet to lose weight rather than having to make their own food choices. Furthermore, previous studies had shown that increases in restraint and decreases in disinhibition during a weight loss intervention were associated with subsequently greater weight lost during a weight maintenance period (Westerterp-Plantenga et al., 1998, Vogels et al., 2005) leading me to predict that this result would also be seen in this study. However, the results suggested that there was no association between changes in restraint or disinhibition during the 8-week low-calorie diet with changes in weight during the weight maintenance period. I also predicted, from the results of previous studies (Vogels and Westerterp-Plantenga, 2007, McGuire et al., 1998) that increases in restraint and decreases in disinhibition (but not hunger) would be associated with less weight regain during the 6-month weight maintenance period. The results showed that, as predicted, increases in restraint and decreases in disinhibition were associated with decreases in weight, during the weight maintenance period following the 8-week low-calorie diet. This result suggests that interventions which increase restraint and decrease disinhibition may be helpful for individuals to maintain their weight following a weight loss intervention rather than regaining the weight they lost, which is often the case (Jeffery et al., 2000).

As discussed above, the results from Chapters 2 and 3 identified that eating behaviours, particularly restraint and disinhibition, may be key factors in understanding overeating and weight control. However, these measures are descriptive behaviours based on self-reported questionnaires concerning how an individual behaves around food. Therefore, Chapters 4 and 5 of this thesis explored the potential mechanisms underlying these behaviours, specifically the cognitive (impulsivity and memory) and motivational factors (hedonic hunger and hunger status) that may control or at least influence food-directed behaviour with the aim of understanding whether, and to what extent, these cognitive and motivational factors contribute to the individual differences in eating behaviours. Given the previous literature (Yeomans et al., 2008, Lyke and Spinella, 2004, Lowe et al., 2009, Didie, 2001), it was hypothesised that both disinhibition and current hunger would be positively associated with impulsivity, hedonic hunger and memory. It was also predicted that restraint would be negatively associated with impulsivity, hedonic hunger and memory despite there being an unclear relationship in previous literature. Both chapters revealed a strong positive association between disinhibited eating (TFEQ disinhibition scores) and restrained eating (TFEQ restraint scores), suggesting that individuals with higher levels of disinhibited eating have higher levels of self-reported restraint and vice versa. The results of Chapter 4 also suggested that individuals with greater impulsivity as measured by the BIS-11 questionnaire and stop signal task, have more disinhibited eating behaviours (TFEQ disinhibition score). However, these results were not replicated in Chapter 5. Chapter 4 also revealed a positive relationship between hedonic hunger and disinhibited eating and levels of hunger TFEQ scores, suggesting that regardless of gender or BMI, an individual's reactions to palatable foods when they are physically present, tasted and available in the environment may lead to

higher levels of hunger and disinhibited eating. These results were not replicated in Chapter 5. However, Chapter 5 did reveal a positive association between levels of self-reported hunger, measured using the TFEQ hunger score and disinhibited eating behaviour.

Chapter 5 also found that those who scored higher on the “WWW” overall THT task (for food images only) reported higher TFEQ disinhibition scores, suggesting that those with a better overall episodic memory are more likely to experience disinhibited eating behaviours, regardless of BMI or dieting status, which contrasts to previous study results, as described in Chapter 5.

Collectively, the results of these chapters suggest that regardless of age, gender, BMI, IQ and dieting status, that behavioural and self-reported impulsivity, hedonic hunger and episodic memory are important factors in predicting disinhibited eating behaviour. Furthermore, both chapters have shown that disinhibition and restraint are positively associated and that hedonic hunger may be important in the levels of self-reported hunger (TFEQ hunger scores).

Another secondary aim of both Chapter 4 and 5 was to explore whether the association between eating behaviours and BMI are explained by cognitive and motivational factors. Given previous literature (Meule and Platte, 2016, Löffler et al., 2015, Dietrich et al., 2014, Kruger et al., 2016b), it was predicted that there may be an interaction between disinhibition and impulsivity on BMI, an interaction between disinhibition and hedonic hunger on BMI and an interaction between restraint and impulsivity. Chapter 4 and 5 both revealed no interactions between any of the eating behaviour, cognitive or motivational variables. However, both studies revealed either a positive or trend

towards a positive association between TFEQ disinhibition and BMI, suggesting that those with higher disinhibited eating, regardless of dieting status (from Chapter 5), had a greater BMI. Thus, suggesting that only disinhibited eating behaviours may lead to obesity and should be explored further to understand why and how these facets relate to one another by identifying any mediators and whether there are specific circumstances in which heightened disinhibited eating behaviour increases the risk of weight gain or not by identifying any moderators.

The third study, which was described in Chapter 4, was also designed to test within-subjects the effect of hunger status by having both a fasted and fed session for each subject. This design allowed me to investigate whether there were differences in eating behaviour, cognitive and motivational factors between 'fasted' and 'fed' days (within subjects) in both lean and overweight individuals. I predicted that there would be significant differences in TFEQ hunger, disinhibition, restraint, memory and hedonic hunger scores between fasted and fed days, but that there would be no significant differences in all measures of impulsivity between fasted and fed sessions. However, my results revealed no significant differences in any of the eating behaviour, cognitive or motivational factors between being fasted or fed. These results suggest that hedonic hunger (PFS), TFEQ disinhibition, hunger and restraint, impulsivity (measured by both the BIS-11 and SRT) as well as episodic memory (measured by the THT) are not considerably affected by daily variations in hunger. Thus, suggesting that completing these measures when hungry or full will not confound the research.

Another aim of both Chapter 4 and 5 was to replicate the findings from a previous study (Cheke et al., 2016) which showed a negative relationship between BMI and episodic

memory as measured by the treasure-hunt task (THT). Both Chapter 4 and 5 found that those with higher BMI had an impaired performance on the THT. While Chapter 4 found an impairment in all subtasks of the THT, including spatial, temporal and item memory, as well as the ability to combine these elements (“What-Where-When” memory). Chapter 5 found an impairment in all subtasks except the item memory subtask, which was likely explained by a ceiling effect in the scores of this specific subtask. Collectively, these results along with the previous results from Cheke et al., (Cheke et al., 2016) provide strong evidence that individuals with a higher BMI have an impaired episodic memory.

Given the negative relationship between BMI and episodic memory and the majority of previous studies suggesting that dieting is beneficial to performance on memory tasks (Boraxbekk et al., 2015, Attuquayefio and Stevenson, 2015), the primary aim of study 4 (Chapter 5) was to investigate, between-subjects, the effects of dieting on episodic memory (measured using the THT), and whether this interacts with BMI. To investigate this I recruited both lean and overweight individuals who were either currently dieting to lose weight or who were control subjects who were not currently dieting. The results of this Chapter suggest that individuals on a diet, regardless of their BMI, have an impaired performance on the THT compared to those currently not on diet. Since both dieting and BMI were negatively associated with episodic memory performance, I predicted that there would be an interaction between BMI and dieting and as such overweight dieters would have a poorer performance in comparison to lean dieters/non-dieters or overweight non-dieters. However, my results revealed no interaction of BMI and dieting status on the THT performance, suggesting that further work is required to understand how BMI and dieting may interact to impair the

performance in episodic memory. As discussed in Chapter 5, this may be explored by comparing diet type or by conducting a prospective, within-subject design study to measure episodic memory before, during and after dieting.

Finally, as discussed in Chapter 4, the THT was developed using only food images, and therefore the impairment in episodic memory with higher BMI as seen in Cheke et al, (Cheke et al., 2016) as well as in Chapter 4 of my thesis could be suggested to be specific to memory for food items. In study 4 (Chapter 5) I aimed to test whether this relationship remained when non-food images were used in the THT. To test this, I created new non-food office stationery item images and re-programmed the THT so that two of the sessions were non-food images and two remained as food tasks so they could be compared. I predicted that both lean and overweight individuals would have a better episodic memory score for non-food images compared to food images, and that there would be no interaction between BMI and image type. Results from study 4 suggested that participants have a poorer episodic memory for food images compared to non-food images, specifically when recalling the image (“what” subtask) and when integrating all information of what, where and when of the image (“WWW” subtask). Thus, the negative association between memory and BMI and dieting status are not specific to food images, but that food images in general are harder to remember.

Collectively, Figure 6.1 tries to tie the results of each of the studies within my thesis into one model and outline the key associations between each of the variables to help consolidate the findings of this thesis (as described later in the Final remarks). The results of this thesis have overall allowed me to explore and interpret individual

differences in eating behaviours and their relationship with motivation, cognition and weight control.

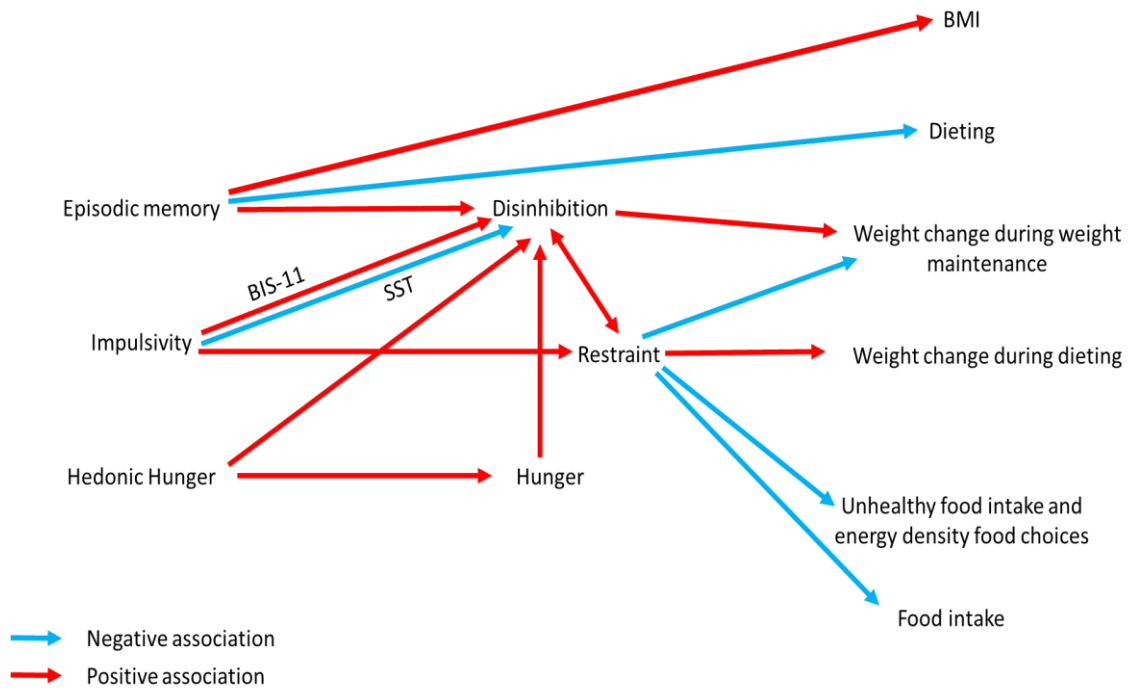


Figure 6.1: A model to show the associations of the overall findings of my thesis

6.2 Strengths and Limitations

There are three key themes to discuss in the overall thesis around the strengths and limitations, given the detailed strength and limitations of each chapter are explained in the discussion of each empirical chapter. Those three themes are: methodology, study sample and study design.

Firstly, the common theme of methodology within my thesis is the use of self-reported questionnaires, such as the DEBQ, TFEW, BIS-11, PFS and EAT-26, to collect data from participants. The advantages of self-report questionnaires are that they are easily administered and are a cheap way, in terms of time and cost, to obtain data. They are also easily scaled up to be delivered to larger samples by using online platforms such as

Survey Monkey. However, it is important to discuss the disadvantages and potential issues with self-report measures. Each of my questionnaires I used had been tested for reliability and validity for each construct as well as testing that it was distinct from other constructs of eating behaviour, as discussed in the methodology sections of each empirical chapter. However, there are several reasons why questionnaires may not be entirely valid. The first, is honesty. For all my experiments, I relied solely on the honesty of my participants. The level at which my participants manage how they appear from an eating behaviour perspective will no doubt vary among individuals. Thus, the level of dishonesty may have varied significantly between groups. Secondly, even those who are trying to be honest and accurate may lack an introspective ability to provide an accurate insight into their behaviour. For example, those who view themselves as having a high level of restraint, others may believe they have a low level of restraint. Thus, perception of one's self could be very different to how others perceive them.

While these disadvantages raise issues of the self-report methodology. As yet the constructs, such as restraint and disinhibition, I was measuring would have been far more difficult to measure with behavioural or "real-world" measures. However, where possible, I tried to include a behavioural and self-report measure, for example by using the BIS-11 questionnaire and the SST for measuring impulsivity. Thirdly, participants also vary in their understanding or interpretation of questions. It is possible that some of my participants did not fully understand and therefore did not answer the question correctly. I was present during the experiments if participants needed my help with a question. However, it is impossible to know if all participants who completed the questionnaire interpreted the questions in the same way.

Another important point to discuss the strengths and limitations of is the study sample used for each experiment. Chapter 3 had the advantage of being conducted prior to this thesis over a 5-year period between 2005-2010, meaning it was a large sample size with 555 male and female participants spread across 8 European countries. This gives a very good representation of the general population. However, the sample sizes for the remaining studies were much smaller with 40-60 participants and split into groups. However, effort was made to make the sample of participants' representative of the U.K. population and so in the experiment described in Chapter 2, participants were recruited from the wider community rather than exclusively from the University of Cambridge. Furthermore, since a greater prevalence of overweight and obesity is found in lower socioeconomic status regions (Observatory, 2012), I recruited groups of lean, overweight and obese individuals who had a comparable variability of income and education levels. The sample sizes from Chapter 2, 4 and 5 are small and further work should include greater numbers of individuals in these studies to see if the associations found are even stronger. Furthermore, a large proportion of my participants in the experiments of Chapter 3, 4 and 5 were females. It may be questionable whether this is representative of the general population. In eating behaviour research, it has been suggested that gender may be an important variable as males and females have been shown to differ in some studied eating behaviours. For example, regardless of BMI, women seem to have higher restraint than men (Provencher et al., 2003, Hainer et al., 2006, Aurelie et al., 2012, Zyriax et al., 2012, Carmody et al., 1995). However, due to the small number of overall participants and smaller number of males in our available population, gender effects could be examined in these chapters of my thesis.

The final discussion point for strengths and limitations of the thesis is the design of each study. The strengths of the design of Chapter 2 is that the buffet was covert and participant were only told to “eat as much as they liked” so that they would be unaware of their food being measured. Studies have shown that when participants believe their food intake is being measured this will affect the amount of food they consume (Robinson and Field, 2015). Thus, it has been suggested that studies which include a food/taste test should attempt to make sure the participant is unaware of the study hypotheses and attempt to conceal the measurement of food intake (Robinson et al., 2017). However, the cross-sectional design meant that participants would only go through the test once and thus any within-subject effects of BMI (with a change of weight) could not be analysed. This was an advantage of Chapter 3, as participants changed their weight and their eating behaviours, it was possible to look at the within-subject effects of change over time. However, for the purposes of this thesis, it would have been better if subjects were not randomised to receive high/low GI and/or high/low protein weight maintenance diets and asked to maintain a normal diet back in the “real world” to look at the real effects post-dieting. In the studies in Chapter 4 and 5, memory tests were conducted purely in the laboratory. Whilst previous research has shown that memory and decision making processes that are studied in the laboratory behave similarly when examined in more “real world” setting (Finn, 2010), future studies should also have a focus on testing outside of the laboratory.

6.3 Applications for weight control

Taken together the results from each experiment, the findings from my thesis raise an interesting question as to whether there may be a potential application for weight loss

and weight maintenance programmes. As discussed in Chapter 3, the results suggest that a weight maintenance programme which increased restraint and decreased disinhibition would be beneficial for weight maintenance following a weight loss intervention. The results from the first study described in Chapter 2 also supports this theory as individuals with low restraint consumed a greater amount of less healthy foods. Thus, increasing an individual's restrained eating behaviour may help to improve their healthy food choices and decreasing the over intake of calories, which may lead to weight loss. To my knowledge there have been no weight loss programmes designed to date which have specifically targeted to improve disinhibited or restrained eating behaviours. However, given the results I reported in Chapters 4 and 5, which showed that impulsivity, hedonic hunger and episodic memory were important factors in disinhibited eating and that hedonic hunger was an important factor in levels of hunger, it may, therefore, be necessary to target cognitive and motivational factors in weight loss or weight maintenance programmes.

One cognitive factor that has been targeted by intervention studies is impulsivity. It has been proposed by some researchers that impaired inhibitory control provoked by appetitive reward cues may encourage the subsequent consumption of those rewards and that these cue-provoked impairments in inhibitory control may play a role in obesity (Jones et al., 2013). Indeed, studies have shown that appetitive food cues, such as pictures of chocolate, induce behavioural approach responses and impairments in inhibitory control (Kemps et al., 2013, Meule et al., 2014). Therefore, studies have trained individuals, using modified versions of the stop signal task or go/no go task, to inhibit simple motor responses to high-energy density food pictures. More specifically, subjects are presented with images of food on a screen and either press a button or

withhold pressing a button depending whether they hear a go or stop signal (e.g., a tone or a letter). In the experimental condition, palatable foods are always presented with stop signals, whereas the control condition does not require individuals to withhold the response to the palatable food stimuli. These laboratory studies initially showed that training individuals to inhibit their response to specific snack food stimuli decreased the subsequent choice (Veling et al., 2013b, Veling et al., 2013a), intake (Veling et al., 2011, Lawrence et al., 2015b, Houben and Jansen, 2011, Houben, 2011, Houben and Jansen, 2015) and self-served portion sizes of those foods (Van Koningsbruggen et al., 2014). Contrary to my thesis results which found no relationship between impulsivity and restraint, some studies found that the effects of this training was particularly pronounced in restrained eaters (Lawrence et al., 2015b, Houben and Jansen, 2011). Furthermore, participants who received four inhibitory control training sessions compared to a control group showed significant weight loss, reductions in daily energy intake and a reduction in rated liking of high-energy density (no-go) foods 6 months after the intervention (Lawrence et al., 2015a). Therefore, these studies suggest that repeatedly practicing inhibitory control over food-related responses using a computer task may be useful to help individuals control their disinhibited eating behaviour, i.e. tendency to overeat in response to food cues and regain the ability to restrain themselves around high calorie foods.

Secondly, whilst the results of Chapters 4 and 5 and previous work (Cheke et al., 2016) have shown that there is a relationship between BMI and memory. If this is a causal relationship, it is possible that improving memory could help with weight control. To my knowledge this has not been tested directly, but there is some evidence that memory can be improved. For example, as discussed in Chapter 1, there is evidence that

enhancing memory for specific consumption episodes (i.e. most recent meal) by recalling a previous meal or focusing on the sensory characteristics of the food as they consumed it is associated with subsequent reduced food consumption levels (Higgs, 2002, Higgs, 2008, Higgs and Donohoe, 2011). In addition, diverting a participant's attention, has been shown to be associated with increased consumption in a later eating session compared to when participants were not distracted (Higgs and Woodward, 2009, Oldham-Cooper et al., 2011). Based on this evidence, it may not be necessary to generally improve memory ability, but rather to supplement and help with memory for that specific event. This is what is being explored by Cheke and colleagues here at the Department of Psychology in Cambridge (also see work by Robinson and colleagues (Robinson et al., 2013b)). A collaboration between the popular brain training app called Peak (BRAINBOW LIMITED) and Dr Lucy Cheke have developed a more specific episodic memory-like task. This task involves prompting memory for recent meals by requiring participants to take pictures of their food using the app at home and then answering questions about their food and the context of its consumption (e.g. what it tasted like, whether it was eaten alone or with others) immediately before consuming the next meal. The study is currently ongoing and the results of this study remain to be fully analysed. However, it is predicted that individuals using the app will lose more weight during a dieting period than those in the control group (Higgs, 2002, Higgs, 2008, Higgs and Donohoe, 2011).

Finally, although computer/mobile phone based apps have been investigated for cognitive factors such as impulsivity and episodic memory, motivational factors such as hedonic hunger are also important aspects of restrained and disinhibited eating behaviour (as shown in Chapters 4 and 5). Unlike impulsivity and episodic memory tasks,

it has been suggested that the best ways to curb hedonic hunger is to keep tempting, highly palatable foods out of the house, eating something healthy, like a piece of fruit before deciding if you want something unhealthy or to keep treats in portion-controlled servings (Lowe et al., 2009). Collectively, these findings suggest that cognitive and motivational interventions and/or changes in lifestyle have the potential to improve public health by reducing energy intake and promoting weight loss.

6.4 Final remarks

The four experimental chapters in this thesis have used several designs to investigate individual differences in eating behaviours and their relationship with motivation, cognition and weight control. The data from the first study described in Chapter 1 suggests that low restraint may lead to higher intake of food overall, but more importantly higher intake of unhealthy foods. The relationship between restraint and energy density in foods remains unclear as low restraint was associated with both higher intake of both low and high energy density foods. It seems restrained eating behaviour has an influence on perceived unhealthy food consumption, but not on foods with different energy densities when not explicitly labelled. Thus, increasing an individual's restrained eating behaviour may be beneficial to weight control as this may lead to consumption of less unhealthy foods. Following this, the second study described in Chapter 2 showed that indeed both increases in restraint and decreases in disinhibition were associated with decreases in weight during a weight maintenance period following an 8-week low energy liquid diet. This study was conducted across 8 European countries and thus these results are generalizable due to the broad study population. The results suggest that behavioural weight loss maintenance interventions which target a decrease

in disinhibition and increase in restraint would be useful for maintaining weight lost during calorie restricted diets. This is an important area to target due to the evidence suggesting that those who are able to lose weight initially, find it difficult to maintain this weight loss (Jeffery et al., 2000) or avoid future weight gain (Stice et al., 2006). This study also suggested that individuals with low restraint before dieting appear to benefit most from a liquid formula weight loss intervention.

The consistency of the findings from the third and fourth studies described in Chapters 4 and 5 of this thesis suggest that impulsivity, restraint, hedonic hunger and episodic memory are important factors in predicting disinhibited eating behaviour. These chapters also suggest that hedonic hunger may be an important factor for levels of self-reported hunger. Furthermore, Chapter 4 suggests that this variance in disinhibition may be an important factor in the variance of BMI. Both studies suggested that episodic memory is negatively associated with BMI. In addition, the final experimental chapter also suggests that dieting has a negative effect on episodic memory and that regardless of BMI or dieting status, individuals overall had a poorer performance on the THT subtasks with food images compared to non-food images. The evidence from this thesis suggests that further work should investigate whether interventions which increase restraint and decrease disinhibition are helpful for weight control. Future work should also investigate changes in episodic memory during dieting and the effects of specific diets on episodic memory performance.

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APPENDICES

Appendix 1: Dutch Eating Behaviour Questionnaire (DEBQ)

Dutch Eating Behaviour Questionnaire - DEBQ

Tatjana van Strien

Enter your name, sex, age and the date. Complete the questions in this booklet as accurately as you can.

Name

Sex

Age

Date

A. Current weight: kg

B. Height: centimetres

C. Has your body weight been constant the past six months?

- ☐ Yes, my weight did not change much in the past six months.
- ☐ No, I lost weight, specifically, I did losekg in the past six months.
- ☐ No, I gained weight, specifically, I did gain.....kg in the past six months.
- ☐ No, sometimes I gained weight and sometimes I lost weight.

D. Highest past weight excluding pregnancy: kg

E. Lowest weight as an adult: kg

F. Have you ever had an episode of eating an amount of food that others would regard unusually large?

- ☐ yes
- ☐ no

Directions. For each item, decide if the item is true about you: never, rarely, sometimes, often or very often. Cross the compartment that corresponds to your rating on this item sheet. Please respond to all items, making sure that that you cross the compartment for the rating that is true about you. If you need to change an answer, make a big cross through the incorrect compartment and make an arrow to the cross on the correct compartment.

		never	rarely	sometimes	often	very often
1	Do you have the desire to eat when you are irritated?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	If food tastes good to you, do you eat more than usual?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	Do you have a desire to eat when you have nothing to do?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	If you have put on weight, do you eat less than you usually do?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	Do you have a desire to eat when you are depressed or discouraged?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	If food smells and looks good, do you eat more than usual?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	How often do you refuse food or drink offered because you are concerned about your weight?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8	Do you have a desire to eat when you are feeling lonely?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9	If you see or smell something delicious, do you have a desire to eat it?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10	Do you have a desire to eat when somebody lets you down?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11	Do you try to eat less at mealtimes than you would like to eat?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12	If you have something delicious to eat, do you eat it straight away?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13	Do you have a desire to eat when you are cross?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14	Do you watch exactly what you eat?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15	If you walk past the baker do you have the desire to buy something delicious?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16	Do you have a desire to eat when you are approaching something unpleasant to happen?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17	Do you deliberately eat foods that are slimming?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18	If you see others eating, do you also have the desire to eat?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

19	When you have eaten too much, do you eat less than usual the following days?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20	Do you get the desire to eat when you are anxious, worried or tense?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21	Do you find it hard to resist eating delicious foods?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22	Do you deliberately eat less in order not to become heavier?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23	Do you have a desire to eat when things are going against you or when things have gone wrong?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24	If you walk past a snack bar or a café, do you have the desire to buy something delicious?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25	Do you have the desire to eat when you are emotionally upset?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26	How often do you try not to eat between meals because you are watching your weight?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27	Do you eat more than usual, when you see others eating?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28	Do you have a desire to eat when you are bored or restless?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
29	How often in the evening do you try not to eat because you are watching your weight?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30	Do you have a desire to eat when you are frightened?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31	Do you take into account your weight with what you eat?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
32	Do you have a desire to eat when you are disappointed?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33	When you are preparing a meal are you inclined to eat something?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Scoring:

Emotional eating diffuse emotions (4 items): item 3, item8, item10 and item28

Emotional eating clearly labelled emotions (9 items): item1, item5, item13, item 16, item20, item23, item25, item30, item32..

Emotional eating (13 items): item3, item8, item10 and item28, item1, item5, item13, item16, item20, item23, item25, item30, item32.

External eating (10 items): item2, item6, item9, item12, item15, item 18, item 21, item24, item27, item33.

Restrained eating (10 items): item 4, item7, item11, item14, item17 , item19, item22, item26, item29, item31.

Appendix 2: Power of Food Scale (PFS)

Power of Food Scale

Participant ID: _____

Date: _____

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

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. 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

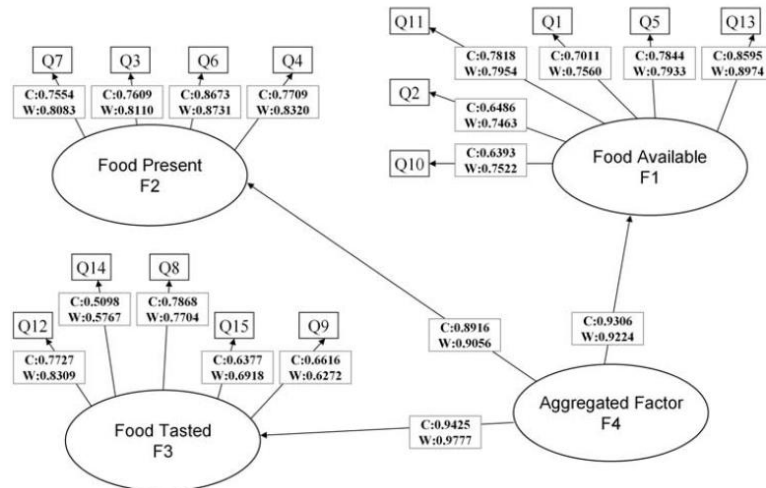


Figure 1 Factor structure of the Power of Food Scale with standardized loadings in the clinical and Web-based studies. C, clinical data set; W, Web survey data set. Item numbers (Q1, Q2, ..., Q15) correspond question numbers in the Appendix.

Scoring of the Power of Food scale: taken from Cappelleri et al., 2009

Appendix 3: Three Factor Eating Questionnaire (TFEQ)

Three-Factor Eating Questionnaire

Stunkard and Messick (1985)

PARTICIPANT ID _____

DATE _____ / _____ / _____

Part I

True/False

- | | | |
|---|---|---|
| 1. When I smell a sizzling steak or see a juicy piece of meat, I find it very difficult to keep from eating, even if I have just finished a meal. | T | F |
| 2. I usually eat too much at social occasions, like parties and picnics. | T | F |
| 3. I am usually so hungry that I eat more than three times a day. | T | F |
| 4. When I have eaten my quota of calories, I am usually good about not eating any more. | T | F |
| 5. Dieting is so hard for me because I just get too hungry. | T | F |
| 6. I deliberately take small helpings as a means of controlling my weight. | T | F |
| 7. Sometimes things just taste so good that I keep on eating even when I am no longer hungry. | T | F |
| 8. Since I am often hungry, I sometimes wish that while I am eating, an expert would tell me that I have had enough or that I can have something more to eat. | T | F |
| 9. When I feel anxious, I find myself eating. | T | F |
| 10. Life is too short to worry about dieting. | T | F |
| 11. Since my weight goes up and down, I have gone on reducing diets more than once. | T | F |
| 12. I often feel so hungry that I just have to eat something. | T | F |
| 13. When I am with someone who is overeating, I usually overeat too. | T | F |
| 14. I have a pretty good idea of the number of calories in common food. | T | F |
| 15. Sometimes when I start eating, I just can't seem to stop. | T | F |
| 16. It is not difficult for me to leave something on my plate. | T | F |
| 17. At certain times of the day, I get hungry because I have gotten used to eating then. | T | F |
| 18. While on a diet, if I eat food that is not allowed, I consciously eat less for a period of time to make up for it. | T | F |

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- | | |
|--|-----|
| 19. Being with someone who is eating often makes me hungry enough to eat also. | T F |
| 20. When I feel blue, I often overeat. | T F |
| 21. I enjoy eating too much to spoil it by counting calories or watching my weight. | T F |
| 22. When I see a real delicacy, I often get so hungry that I have to eat it right away. | T F |
| 23. I often stop eating when I am not really full as a conscious means of limiting the amount that I eat. | T F |
| 24. I get so hungry that my stomach often seems like a bottomless pit. | T F |
| 25. My weight has hardly changed at all in the last ten years. | T F |
| 26. I am always hungry so it is hard for me to stop eating before I finish the food on my plate. | T F |
| 27. When I feel lonely, I console myself by eating. | T F |
| 28. I consciously hold back at meals in order not to gain weight. | T F |
| 29. I sometimes get very hungry late in the evening or at night. | T F |
| 30. I eat anything I want, any time I want. | T F |
| 31. Without even thinking about it, I take a long time to eat. | T F |
| 32. I count calories as a conscious means of controlling my weight. | T F |
| 33. I do not eat some foods because they make me fat. | T F |
| 34. I am always hungry enough to eat at any time. | T F |
| 35. I pay a great deal of attention to changes in my figure. | T F |
| 36. While on a diet, I eat a lot of food that is not allowed, I often then splurge and eat other high calorie foods. | T F |

Part II

Directions: Please answer the following questions by circling the number above the response that is appropriate to you.

37. How often are you dieting in a conscious effort to control your weight?
- | | | | |
|--------|-----------|---------|--------|
| 1 | 2 | 3 | 4 |
| rarely | sometimes | usually | always |

38. Would a weight fluctuation of 5lbs affect the way you live your life?
- | | | | |
|------------|----------|------------|-----------|
| 1 | 2 | 3 | 4 |
| not at all | slightly | moderately | very much |
39. How often do you feel hungry?
- | | | | |
|-------------------|-------------------------|---------------------|---------------|
| 1 | 2 | 3 | 4 |
| only at mealtimes | sometimes between meals | often between meals | almost always |
40. Do your feelings of guilt about overeating help you to control your food intake?
- | | | | |
|-------|--------|-------|--------|
| 1 | 2 | 3 | 4 |
| never | rarely | often | always |
41. How difficult would it be for you to stop eating halfway through dinner and not eat for the next four hours?
- | | | | |
|------|--------------------|----------------------|----------------|
| 1 | 2 | 3 | 4 |
| easy | slightly difficult | moderately difficult | very difficult |
42. How conscious are you of what you are eating?
- | | | | |
|------------|----------|------------|-----------|
| 1 | 2 | 3 | 4 |
| not at all | slightly | moderately | extremely |
43. How frequently do you avoid 'stocking up' on tempting foods?
- | | | | |
|--------------|--------|---------|---------------|
| 1 | 2 | 3 | 4 |
| almost never | seldom | usually | almost always |
44. How likely are you to shop for low calorie foods?
- | | | | |
|----------|-------------------|-------------------|-------------|
| 1 | 2 | 3 | 4 |
| unlikely | slightly unlikely | moderately likely | very likely |
45. Do you eat sensibly in front of others and splurge alone?
- | | | | |
|-------|--------|-------|--------|
| 1 | 2 | 3 | 4 |
| never | rarely | often | always |
46. How likely are you to consciously eat slowly in order to cut down on how much you eat?
- | | | | |
|----------|-----------------|-------------------|-------------|
| 1 | 2 | 3 | 4 |
| unlikely | slightly likely | moderately likely | very likely |
47. How frequently do you skip dessert because you are no longer hungry?
- | | | | |
|--------------|--------|----------------------|------------------|
| 1 | 2 | 3 | 4 |
| almost never | seldom | at least once a week | almost every day |
48. How likely are you to consciously eat less than you want?
- | | | | |
|----------|-----------------|-------------------|-------------|
| 1 | 2 | 3 | 4 |
| unlikely | slightly likely | moderately likely | very likely |
49. Do you go on eating binges though you are not hungry?
- | | | | |
|-------|--------|-----------|----------------------|
| 1 | 2 | 3 | 4 |
| never | rarely | sometimes | at least once a week |

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

0

eat whatever you want, whenever you want it

1

usually eat whatever you want, whenever you want it

2

often eat whatever you want, whenever you want it

3

often limit food intake, but often 'give in'

4

usually limit food intake, rarely 'give in'

5

constantly limiting food intake, never 'giving in'

51. To what extent does this statement describe your eating behaviour? 'I start dieting in the morning but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising myself to start dieting again tomorrow.'

1

not like me

2

little like me

3

pretty good
description
of me

4

describes me
perfectly

Three-factor eating questionnaire Scoring Details

Factor I = dietary restraint (max score 21)

Factor II = disinhibition (max score 16)

Factor III = hunger (max score 14)

Part I

1 point for each correct answer. Below are the correct answers and in brackets is the number factor it corresponds to:

1. T (2)
2. T (2)
3. T (3)
4. T (1)
5. T (3)
6. T (1)
7. T (2)
8. T (3)
9. T (2)
10. F (1)
11. T (2)
12. T (3)
13. T (2)
14. T (1)
15. T (2)
16. F (2)
17. T (3)
18. T (1)
19. T (3)
20. T (2)
21. F (1)
22. T (3)
23. T (1)
24. T (3)
25. F (2)
26. T (3)
27. T (2)
28. T (1)
29. T (3)
30. F (1)
31. F (2)
32. T (1)
33. T (1)
34. T (3)
35. T (1)
36. T (2)

Part II

The direction of the question is determined by splitting the responses in the middle. If it has a + next to it, those responses to the left of the middle are given zero and those to the right of the middle are given one point. Vice versa for those with a -. E.g. Question 37 (labelled +), answers 3 or 4 are given 1 point, answers 1 or 2 are given zero.

37. + (1)
38. + (1)
39. + (3)

- 40. + (1)
- 41. + (3)
- 42. + (1)
- 43. + (1)
- 44. + (1)
- 45. + (2)
- 46. + (1)
- 47. - (3)
- 48. + (1)
- 49. + (2)
- 50. + (1)
- 51. + (2)

Appendix 4: Barratt Impulsive Scale (BIS-11)

DIRECTIONS: People differ in the ways they act and think in different situations. This is a test to measure some of the ways in which you act and think. Read each statement and put an X on the appropriate circle on the right side of this page. Do not spend too much time on any statement. Answer quickly and honestly.				
	① Rarely/Never	② Occasionally	③ Often	④ Almost Always/Always
1 I plan tasks carefully.	①	②	③	④
2 I do things without thinking.	①	②	③	④
3 I make-up my mind quickly.	①	②	③	④
4 I am happy-go-lucky.	①	②	③	④
5 I don't "pay attention."	①	②	③	④
6 I have "racing" thoughts.	①	②	③	④
7 I plan trips well ahead of time.	①	②	③	④
8 I am self controlled.	①	②	③	④
9 I concentrate easily.	①	②	③	④
10 I save regularly.	①	②	③	④
11 I "squirm" at plays or lectures.	①	②	③	④
12 I am a careful thinker.	①	②	③	④
13 I plan for job security.	①	②	③	④
14 I say things without thinking.	①	②	③	④
15 I like to think about complex problems.	①	②	③	④
16 I change jobs.	①	②	③	④
17 I act "on impulse."	①	②	③	④
18 I get easily bored when solving thought problems.	①	②	③	④
19 I act on the spur of the moment.	①	②	③	④
20 I am a steady thinker.	①	②	③	④
21 I change residences.	①	②	③	④
22 I buy things on impulse.	①	②	③	④
23 I can only think about one thing at a time.	①	②	③	④
24 I change hobbies.	①	②	③	④
25 I spend or charge more than I earn.	①	②	③	④
26 I often have extraneous thoughts when thinking.	①	②	③	④
27 I am more interested in the present than the future.	①	②	③	④
28 I am restless at the theater or lectures.	①	②	③	④
29 I like puzzles.	①	②	③	④
30 I am future oriented.	①	②	③	④

Patton, Stanford, Barratt (1995). *J Clin Psy*, vol. 51, pp. 768-774

Barratt Impulsiveness Scale 11 – Factor Structure and Scoring			
2nd Order Factors	1st Order Factors	# of items	Items contributing to each subscale
Attentional	Attention	5	5, 9*, 11, 20*, 28
	Cognitive Instability	3	6, 24, 26
Motor	Motor	7	2, 3, 4, 17, 19, 22, 25
	Perseverance	4	16, 21, 23, 30*
Nonplanning	Self-Control	6	1*, 7*, 8*, 12*, 13*, 14
	Cognitive Complexity	5	10*, 15*, 18, 27, 29*
			*reverse scored items

Appendix 5: EAT-26 Questionnaire



EAT-26 Questionnaire

Garner & Garfinkel (1979); Garner *et al.*, (1982)

PARTICIPANT ID _____

DATE ____ / ____ / ____

Please respond to how each of the following statements apply to you:

	Always	Usually	Often	Sometimes	Rarely	Never	Score
1. Am terrified about being overweight	0	0	0	0	0	0	_____
2. Avoid eating when I am hungry	0	0	0	0	0	0	_____
3. Find myself preoccupied with food	0	0	0	0	0	0	_____
4. Have gone on eating binges where I feel that I may not be able to stop	0	0	0	0	0	0	_____
5. Cut my food into small pieces	0	0	0	0	0	0	_____
6. Aware of the calorie content of foods that I eat	0	0	0	0	0	0	_____
7. Particularly avoid food with a high carbohydrate content (i.e. bread, rice, potatoes, etc.)	0	0	0	0	0	0	_____
8. Feel that others would prefer if I ate more	0	0	0	0	0	0	_____
9. Vomit after I have eaten	0	0	0	0	0	0	_____
10. Feel extremely guilty after eating	0	0	0	0	0	0	_____
11. Am preoccupied with a desire to be thinner	0	0	0	0	0	0	_____
12. Think about burning up calories when I exercise	0	0	0	0	0	0	_____
13. Other people think that I am too thin	0	0	0	0	0	0	_____
14. Am preoccupied with the thought of having fat on my body	0	0	0	0	0	0	_____
15. Take longer than others to eat my meals	0	0	0	0	0	0	_____
16. Avoid foods with sugar in them	0	0	0	0	0	0	_____
17. Eat diet foods	0	0	0	0	0	0	_____
18. Feel that food controls my life	0	0	0	0	0	0	_____
19. Display self-control around food	0	0	0	0	0	0	_____
20. Feel that others pressure me to eat	0	0	0	0	0	0	_____
21. Give too much time and thought to food	0	0	0	0	0	0	_____
22. Feel uncomfortable after eating sweets	0	0	0	0	0	0	_____
23. Engage in dieting behaviour	0	0	0	0	0	0	_____
24. Like my stomach to be empty	0	0	0	0	0	0	_____
25. Enjoy trying new rich foods	0	0	0	0	0	0	_____
26. Have the impulse to vomit after meals	0	0	0	0	0	0	_____

TOTAL SCORE _____

PTO

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Please respond to each of the following questions:

1. Have you gone on eating binges where you feel that you may not be able to stop?
(Eating much more than most people would eat under the same circumstances)

No ☐ Yes ☐ → How many times in the last 6 months? _____

2. Have you ever made yourself sick (vomited) to control your weight or shape?

No ☐ Yes ☐ → How many times in the last 6 months? _____

3. Have you ever used laxatives, diet pills or diuretics (water pills) to control your weight or shape?

No ☐ Yes ☐ → How many times in the last 6 months? _____

4. Have you ever been treated for an eating disorder?

No ☐ Yes ☐ → When? _____

5. Have you recently thought of or attempted suicide?

No ☐ Yes ☐ → When? _____

EAT-26 Scoring Details

For all items **except #25**, each of the responses receives the following value:

Always	=	3
Usually	=	2
Often	=	1
Sometimes	=	0
Rarely	=	0
Never	=	0

For **item #25**, the responses receive these values:

Always	=	0
Usually	=	0
Often	=	0
Sometimes	=	1
Rarely	=	2
Never	=	3

Appendix 6: Appetite Questionnaire

PROTECT – PRIVATE

Participant ID: _____

Date: ____/____/____

Visit number: _____

Appetite Questionnaire

Please answer the following questions by placing a vertical mark through the line.
Regard the ends of each line as indicating the most extreme sensation you have ever felt.

1. How **hungry** are you?

Not at all _____ Extremely

2. How **full** are you?

Not at all _____ Extremely

Appendix 7: Treasure Hunt Task images of food and non-food items during the object recognition subtask

