Control of eating after bariatric surgery

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

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"It's a doctorate, it's supposed to hurt."

- *Professor Stephen Morley*

Abstract

Whilst bariatric surgery is an effective intervention for life-threatening obesity, a substantial proportion of patients will continue to struggle to control their eating after surgery. Food cravings – the intense desire for a specific food or food group – are a key trigger for maladaptive eating, and are related to external cues and internal mental imagery. However, there is little known about the phenomenological experience of food cravings in people who have received bariatric surgery, or if there are any differences between types of bariatric surgery. This study recruited 43 bariatric patients between one and ten years post-surgery who reported all food cravings experienced over the course of one week using critical incident analysis methodology, resulting in a dataset of 128 cravings. The experience of people with gastric banding versus restructuring surgeries were compared, and mixed-model analyses were used to identify key predictive factors for the intensity and the resistibility of food cravings. Two to four cravings were experienced weekly: most often preceded by thinking about the food, most frequently for savoury foods, occurring in the early afternoon and within the first two hours after a meal. The majority of cravings (75%) resulted in an eating episode. Days in which a craving occurred were characterised by greater hunger, irritability and lower eating control. People with restructuring surgeries rated cravings as stronger and more difficult to resist, and more often ate after the craving than people with gastric bands, but this is likely to be due to differences between sample. Participants identified internal sensory imagery as part of their craving experience, and external sensory cues (seeing, smelling and eating the craved food) best predicted craving intensity. It is hoped that this study will help bariatric surgery candidates, those living with surgery and their clinicians to understand and anticipate food cravings, and lead to the development of effective interventions.

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List of Abbreviations

ACT: Acceptance and Commitment Therapy

BMI: Body mass index

BOS: Bristol Online Surveys

CEQ-S: Craving Experience Questionnaire - Sensory

CIA: Critical incident analysis

DASS: Depression anxiety stress scales

EDE-Q: Eating disorder examination questionnaire

EI: Elaborated intrusion

EMA: Ecological momentary assessment

FCI: Food Craving Inventory

GP: General Practitioner

LAGB: Laparoscopic gastric banding

LSG: Laparoscopic sleeve gastrectomy

NICE: National Institute for Clinical Excellence

NHS: National Health Service

NRS: Numerical rating scale

RCT: Randomised controlled trial

RYGB: Roux-en-Y gastric bypass

SUIS: Spontaneous use of imagery scale

TFEQ: Three-factor eating questionnaire

VAS: Visual analogue scale

VLCD: Very low calorie diet

WHO: World Health Organisation

INTRODUCTION

Obesity is one of the world's primary health challenges; linked to chronic health conditions, disability and premature death. For those struggling with excessive weight gain, bariatric surgery is a life-saving and life-changing operation. However, some people continue to struggle to control their eating after they have received bariatric surgery. Food craving – the intense desire to eat a specific food or food group – has been implicated in over-eating and weight gain, but is not well understood in the community of people living with a bariatric procedure. Furthermore, there is mixed evidence about the way different forms of bariatric surgery affect post-surgery outcomes and experiences. Current theories of food craving implicate environmental cues and internal sensory imagery as key facets of craving experience which may be amenable to clinical intervention via guided imagery and mindfulness techniques. This thesis investigate the frequency and phenomenology of food cravings in a sample of the population of people who have received bariatric surgery up to ten years previously, comparing the experience of people who have received different types of surgical procedure, and explore how craving experience relates to weight change, eating behaviours and mental imagery.

LITERATURE REVIEW

Obesity

Obesity, the excessive accumulation of bodily fat, is diagnosed by calculating body mass index (BMI) by dividing weight in kilograms by height in metres squared. In the British population, the National Health Service (NHS) categorises BMI values between 18.5 and 24.9 kg/m^2 as healthy, whereas BMI values from 25.0 to 29.9 kg/m^2 are classified as overweight, and BMI values over 30 kg/m^2 are deemed to be obese. Moreover, subcategories of obesity have been defined: BMI values between 30 kg/m^2 and 34.9 kg/m^2 are defined as obesity-I, BMI values exceeding 35.0 kg/m^2 are defined as obesity-II and those exceeding 40.0 kg/m^2 as obesity-III. Variations of these BMI values are provided for different ethnic groups. Despite the rudimentary nature of the BMI calculation which cannot distinguish between lean muscle and fat mass, it remains the standard measure of weight classification for the general population.

Historically, obesity was a rare occurrence but there are now more deaths worldwide related to having a BMI that is overweight or obese than deaths from malnourishment (World Health Organisation [WHO], 2009). In the UK, statistics from 2015/2016 revealed 58% women and 68% men had BMIs that classed them as being overweight or as having obesity. For every 100 adults in the UK, 36 are deemed to have an BMI in the overweight range, 24 have a BMI in the obese range, and three have a BMI classed as obesity-II or obesity-III. Furthermore there were 525,000 admissions to NHS hospitals in 2016 where obesity was recorded as a contributing factor for that admission (NHS Digital, 2017). Having a BMI in the obese range is associated with the development of significant secondary health conditions and disability including type-II diabetes, chronic pain conditions, cancers, stroke and coronary heart disease and, in turn, premature death. In addition, psychological issues

such as low self-esteem, depression and anxiety are common in those with obesity; with one study estimating nearly a quarter of people with obesity had symptoms of clinical depression (Carey et al., 2014). It is estimated that the NHS in England spent £6.1 billion on overweight- and obesity-related ill-health between 2014 and 2015, with a wider economic cost to the UK of £27 billion. This is projected to rise to a UK-wide NHS cost of £9.7 billion by 2050, with wider costs to society estimated to reach £49.9 billion per year (Public Health England, 2015). Whilst obesity is classed as a disease in its own right in the United States (as it decreases life expectancy, impairs the normal functioning of the body, and it can be caused by genetic factors), WHO and the NHS defines obesity as a preventable condition that is a risk factor for secondary illnesses. In order to prevent obesity, it is necessary to understand why it develops.

Why do people develop obesity?

The common understanding of obesity it that it is caused by an imbalance between the amount of energy consumed in calories via food and drinks compared to the amount of energy expended by physical activity. Indeed, this theory is supported by the NHS itself who state on their public website that obesity is the result of "*eating excessive amounts of cheap, high-calorie food and spending a lot of time sitting down, at desks, on sofas or in cars"* (2016). This simplistic definition of obesity gives the false hope of a straightforward solution: just eat less and exercise more. However, this definition fails to account for the number of complex and interacting factors which affect an individual's susceptibility to accumulate fat or for behaviours which may underpin fat accumulation. Biological factors include genetic predisposition for weight gain (Loos & Bouchard, 2008; Yang, Kelly, & He, 2007), variations in gut flora (DiBaise et al., 2008), and the impact of medications taken for primary illnesses that result in secondary weight gain (such as antidepressant medication; Patten et al.,

2009). Moreover, Volkow, Wang and Baler (2011) suggest differences at a neurological level influence obesity; arguing that obesity is associated with poorer executive functioning which results in an reduced ability to inhibit urges to eat in combination with increased sensitivity to the effect of food on the dopaminergic reward circuitry.

Townsend and Lake (2017) have observed that, for some, the advancement of technology has afforded the luxury of physically undemanding employment and travel solutions, alongside the ready availability of pervasively-marketed, affordable, and energy-dense convenience foods. In contrast, exercise and sporting activities can be an expensive luxury, there is limited town planning for cycle and walking routes and there is an absence of advertising and marketing for healthier, unprocessed foods. These environmental and societal structures that encourage increased unhealthy food intake and discourage activity are termed the *"obesogenic environment"* (Townsend & Lake, 2017). Cultural factors also play a role: both the broader societal culture in which we live, and the more personal family culture in which we are raised. In developed countries, people in lower socio-economic groups have a higher incidence of obesity, whilst in the developing world the reverse is true. This difference is attributed to the cultural value placed on different body types (Sobal & Stunkard, 1989; McLaren, 2007). Within the family, parental behaviours, attitudes and control over eating (such as the extent to which parents monitor their child's diet and weight) influence the development of obesity in childhood (Tzou & Chu, 2012). Additionally, there is a complex relationship between emotions and eating behaviour. Negative emotions including stress, fear, sadness and anger have been shown to both increase and decrease appetite, food intake and pleasure from eating (Macht, 2008). Adding to the complexity of the picture, a minority of people with obesity (10-34%) do not

appear to experience any negative health consequences as a result of their high BMI. The protective mechanisms for "metabolically healthy obesity" are unknown, but could include greater adipose tissue inflammation or a different capacity for adipose tissue expansion (Muñoz-Garach, Cornejo-Paraja & Tinahones, 2016), although the topic is controversial within the medical literature. Undoubtedly, the rising rate of obesity is driven by a complex picture of interacting environmental, societal, behavioural, cultural, familial and biological factors which are difficult to disentangle.

Obesity treatment

Whilst not all people with obesity will desire weight-loss, those who do seek additional support to reduce their obesity are treated within the four tiers of obesity management commissioned by the NHS as per National Institute for Health and Care Excellence (NICE) guidance (2014). At tier one, General Practitioners (GPs) assess and monitor their patients' weight and eating habits, and provide advice about healthy eating and physical activity. Tier two interventions focus on community weight management programmes including referrals to commercial weight loss groups (known as *"slimming on referral"*) and participation in monitored exercise programmes (*"exercise on referral")*. For those who require more intensive intervention, tier three specialist multi-disciplinary weight management clinics provide closely monitored evidence-based diet programmes such as a Very Low Calorie Diet (VCLD; comprising less than 600 calories per day), medications (e.g. drugs to prevent the absorption of fats such as orlistat) and psychological interventions that address difficulties managing weight. However, if these interventions are unsuccessful, life-threatening obesity can be treated via tier four: surgical intervention (Capehorn, Haslam & Welbourn, 2016).

Bariatric surgery

Current guidance (NICE, 2014) recommends that bariatric surgery should be considered for all patients with a BMI greater than 40 kg/m^2. However, if there is a co-morbid obesity-related disease present, patients are offered an expedited assessment for surgery at 35kg/m^2, and for patients with recent-onset type-II diabetes, assessments for surgery can be made at 30kg/m^2. Surgery is the first-line treatment for patients with a BMI exceeding 50kg/m^2, ahead of lifestyle or drug treatments. According to a recent cohort study, the most commonly used types of weight loss surgery in the UK are: Roux-en-Y gastric bypass (47%), gastric banding (36%), sleeve gastrectomy (16%) and duodenal switch (0.1%; Douglas, Bhaskharan, Batterham & Smeeth, 2015). The decision to proceed with one form of surgery over the alternatives is made jointly between patient and surgeon based on the patient's needs and preferences, alongside the surgeon's clinical experience and surgical specialism.

Bariatric surgeries aim to increase weight loss by reducing the capacity of the stomach (called a restrictive method), by decreasing the absorption of nutrients (called a malabsorptive method), or by a combination of both methods. In addition, the types of food that can be tolerated by the body are altered resulting in a reduced tolerance for fatty or sugary foods. In the past, restrictive and malabsorptive methods were considered distinct, but current opinion regards all bariatric surgeries as a combination of both these methods in addition to other more complex mechanisms; including changes in energy metabolism, induction of satiety, changes in taste and food aversion, changes in gut peptides, and neural and hormonal mediators (O'Brien, 2010; Tam et al., 2011). Each surgery has different gastro-intestinal outcomes with regards to physical capacity, absorption, digestion and hormonal balance which effect the body's ability to process foods, and thus storage of energy (Meek, Lewis, Reimann,

Gribble & Park, 2016). However, a broad distinction can be drawn between gastric banding - in which the digestive system remains intact but a medical device is added to the stomach - and procedures in which the digestive system is surgically restructured. The main four forms of surgery are discussed in more detail below, but first the intact digestive system is briefly described.

The intact digestive system

In an intact digestive system, the food bolus travels down the oesophagus into the stomach. The stomach is the main organ of the digestive system. It produces ghrelin, a hormone which induces the feeling of hunger and causes the release of gastric acids and digestive enzymes into the stomach. These acids and enzymes break down food into its constituent molecules to allow for uptake into the body. After the stomach, the food bolus moves into the upper intestine (duodenum, jejunum and ileum) where most of the nutrients and calories are absorbed. The remaining bolus continues through to the large intestine, comprised of the colon and anus. Here, the remaining digestible matter is fermented and the last nutrients absorbed before excretion from the body.

Roux-en-Y gastric bypass (RYGB)

In RYGB procedures, a small pouch roughly the size of an egg is created out of the patient's stomach. The oesophagus is connected to the jejunum via this small pouch, effectively reducing the size of the stomach and removing the duodenum. It therefore reduces the amount of food that can be eaten in one meal, reduces digestive processes and response to hormones, and limits the calories absorbed. This operation is usually performed laparoscopically (i.e. "keyhole surgery") but can also be performed as open surgery**.** Unsurprisingly, this major restructuring of the digestive

tract involves the risk of significant secondary effects including: leakage at the surgical junctions, blockages in the tract, and vitamin deficiencies and/or anaemia due to reduced absorption and vomiting. Eating foods high in glucose or sucrose can cause "dumping syndrome" characterised by diarrhoea, nausea, a racing heart, tremors and fainting.

Laparoscopic sleeve gastrectomy (LSG)

Gastrectomy surgeries refer to any surgery where part or all of the stomach is removed. In total gastrectomies, the whole stomach is removed and instead the oesophagus is connected directly to the duodenum. More common is the sleeve gastrectomy, in which 75% of the stomach is removed from the left side. The remaining stomach is resealed so it is longer and thinner in shape (like a sleeve). The term partial gastrectomy is used if a smaller proportion of the stomach is removed. As with RYGB, possible secondary effects of LSG include nausea, vomiting, leakage from the surgical junctions, acid reflux, dumping syndrome, vitamin deficiency/anaemia and infection. Morning vomiting is a common complication of gastrectomy due to the accumulation of bile in the duodenum spilling into the remaining portion of stomach.

Duodenal switch

This procedure involves removal of approximately 70% of the stomach and most of the duodenum. In addition, a portion of the small intestine is rerouted to reduce the amount of time the food can be absorbed into the body, with the rerouting especially targeting fat absorption. After a duodenal switch, only 20% of a patient's total fat intake can be absorbed by the intestines. Duodenal switches have several additional advantages over other methods including: increased control of type-II diabetes, reduced experience of dumping syndrome and a reduction in ghrelin production.

However, duodenal switch still results in vitamin deficiencies/anaemia and diarrhoea; and comes with the risk of infection, leakage and blockage. Duodenal switch is the most costly and complicated bariatric procedure and thus is performed infrequently in the UK.

Laparoscopic adjustable gastric banding (LAGB).

LAGB is distinct from the previous three surgeries as it requires no restructuring or removal of the digestive tract, but instead the addition of a medical device. In this procedure, an adjustable band is placed around the stomach, usually via laparoscopic surgery, which limits the capacity of the stomach. Once the band is in place, the surgeon uses a subcutaneous port to add or remove saline solution to inflate or deflate the band as necessary to achieve the patient's desired weight loss. Weight loss from LAGB is slower than weight loss from other methods and can be entirely reversed with the removal of the banding device, so is more frequently offered to patients with less severe obesity. As this method predominantly reduces capacity (absorption is affected but to a lesser extent), some of the side effects described above for the RYGB, LSG and duodenal switch are lessened. Gastric bands also have a lower mortality rate compared to the alternative surgical restructuring procedures. However, complications can arise if the band slips from its position, erodes into the stomach or it leaks due to punctures or disconnections. Additional risks include inflamed stomach lining, heartburn and stomach ulcers, or an infection at the subcutaneous port. Eating more than the capacity of the banded stomach will cause vomiting.

Follow-up care after bariatric surgery

NICE guidance (2014) states a minimum of two years of follow-up care should be provided by the bariatric surgery service. This should include monitoring of nutrition and vitamin/mineral deficiencies, monitoring for comorbidities, medication

reviews plus individual psychological support. Patients should also continue to be offered healthy diet and physical activity advice and support; as well as referral to community support groups. Initially, patients will need to stick to a liquid-only diet whilst they recover from surgery, before gradually introducing small portions of easily-tolerated foods. Living with a bariatric procedure in the long-term requires eating a portion-controlled, calorie-controlled and nutritionally-balanced diet to prevent secondary effects such as dumping syndrome, vomiting, nausea, and vitamin and mineral deficiencies. Patients are also encouraged to do moderate exercise to assist with weight loss and improve general health.

Efficacy of bariatric surgeries

Most the research into the efficacy of bariatric surgery focuses on immediate post-surgical weight loss, reductions in co-morbid diseases and improvements in quality of life. This is understandable, as these form the most important outcomes from the medical justification for the surgery – to prevent obesity-related death and improve associated health complications**.** To this end, bariatric surgeries are successful. Research beginning in the 1980s has shown that bariatric surgeries result in significant weight loss compared to control groups (Andersen, Backer, Astrup & Quaade, 1987; Mingone et al., 2002; Sjöström, 2003; von Mach et al, 2004). A recent Cochrane Review (Colquitt, Pickett, Loveman & Frampton, 2014) of twenty-two trials including just under 1800 patients confirms that, overall, bariatric surgery is more effective at helping patients lose weight and makes greater improvements in health-related quality of life and type-II diabetes than non-surgical approaches over the three years post-surgery. Radical weight loss and health improvements associated with bariatric surgery also prompt changes in other areas of people's lives. A recent ten year follow-up study showed that bariatric patients who were married at the time

of surgery were more likely to seek a divorce, and those who were unmarried or single were more likely to enter a new relationship or marriage compared to a control group undergoing non-surgical obesity healthcare, and the effect was more pronounced the more weight was lost (Bruze et al., 2018).

However, despite the clear benefits, bariatric surgery is not without its risks. Where there are difficulties, LAGB can be easily removed, but restructuring surgeries require complex, open surgery to attempt to reverse the procedure as much as possible. A large scale review of over 40,000 surgeries in New York showed revisional surgery was required for 26% of LAGB surgeries, 10% of SG and 5% of RYGB. Indeed, long-term follow up has suggested that up to 50% of LAGB patients have their band removed (Himpens, Cadiere, Bazi, Vouche, Cadiere & Dapri, 2011) and the majority of band removals result in restructuring surgeries to ensure weight loss is continued (Altieri, Yang, Lizhou, Blackstone, Konstantinos, & Pryor, 2018). Rarely, bariatric surgery results in death either by complications of the surgery (Goldfelder, Ren & Gill., 2006) or suicide, which has been associated with difficulty controlling post-operative eating and weight (Tindle, Omalu, Courcoulas, Marcus, Hammers, & Kuller, 2010). Consequently, an understanding of which surgery is the most effective at reducing and controlling weight with the most tolerable side effects would be extremely valuable in order to provide improved patient care.

Unfortunately, no clear consensus has emerged as to which surgical procedure has better outcomes, and the Cochrane Institute graded the quality of the evidence base in this area of its review as low or very low. As above, most trials focus on the weight loss post-surgery. In a Cochrane review report, three randomised controlled trials (RCTs) showed that more substantial weight losses were made after five years by those who had laparoscopic RYGB compared to LAGB. Other RCTs have shown

greater weight loss resulting from duodenal switch over RYGB, and better outcomes from LSG compared to LAGB. However, seven trials which compared open-surgery RYGB with laparoscopic RYGB and LSG found no clear pattern for superiority of outcomes. Indeed, the authors concluded that there was insufficient evidence at present to make a judgement about effectiveness of one surgery over another (Colquitt, Pickett, Loveman & Frampton, 2014). In a more recent cohort study, RYGB resulted in the greatest weight loss, followed by LSG then LAGB (Douglas et al., 2015). In terms of non-weight related outcomes between surgeries, there is a shortage of research. A comparison of RYGB, LSG and LAGB showed LSG performed best in food tolerance and self-rated gastrointestinal health (e.g. incidence of diarrhoea, constipation, nausea and vomiting) two to four years post-surgery, followed closely by RYGB. LAGB had the poorest outcomes. The authors suggest LAGB may perform poorer than restructuring surgeries due to: the band itself (an "obstructive foreign body" which is difficult to tolerate), the need for ongoing band adjustment (which may be under- or over-inflated), and band complications such as erosion and slippage. In contrast, the restructured gastrointestinal tract can adapt over time (Overs, Freeman, Zarshenas, Walton & Jorgensen, 2012). Indeed, comparison of three restructuring surgeries (RYGB, duodenal switch and bilopancreatic diversion) showed no differences in the amount or types of foods tolerated after surgery, satisfaction with eating or frequency of vomiting, although there was no comparison to LAGB (Cano-Valderrama, Sánchez-Pernaute, Rubio-Herrera, Domínguez-Serrano, & Torres-García, 2017). Accordingly, the current *By-Band-Sleeve* trial led by the University of Bristol is systematically randomising participating patients into surgical groups in order to to better understand the influence of surgical type on outcomes of surgery. The trial is due to end in 2020.

Maladaptive and disordered eating patterns following bariatric surgery

Most patients maintain their weight loss by following the specialist aftercare advice received post-surgery. However, a substantial subgroup of patients will struggle to follow the controlled post-surgery diet and exercise regimes. Estimates suggest that between 20% and 50% patients will regain the weight they lost via surgery (Budak & Thomas, 2009; Benotti & Forse, 1995). Disordered eating may account for at least some of this weight gain as research suggests that around a quarter of patients will exhibit maladaptive eating behaviours post-surgery (Rusch & Andris, 2007). A study by Conceiçao et al (2014) showed that post-surgical patients report a reduction in maladaptive eating behaviours in the first 10 months following the procedure, but subjective binge eating episodes and "picking and nibbling" were reported at one- and two-years follow-up, suggesting that the initial positive gains from the surgery may not be sustained long-term. Common maladaptive eating patterns described in the literature are binge eating, comfort eating, loss-of-control eating and grazing (eating frequent, small amounts; Conceiçao et al., 2014). Post-surgical binge eating has drawn particular attention in the literature, estimated to occur in up to half of patients (Niego, Kofman, Weiss & Geliebter, 2007). These eating patterns are associated with poorer outcomes after surgery in terms of decreased weight loss, increased weight gain and poorer psychological wellbeing (Lane & Szabó, 2013; Meany, Conceiçao & Mitchell, 2014).

Qualitative interviews with post-bariatric patients illuminate the complexity of controlling eating after a weight-loss procedure. A systematic review and synthesis of 41 papers suggested three main themes – striving for control over eating, the wish for normality unburdened by physical and psychological problems, and ambivalence towards the surgery. Gaining control over eating was complicated by difficulty

determining what foods (and in what amount) their new digestive system could tolerate without triggering “dumping syndrome”, the shame and guilt associated with unsatisfactory weight loss or regain of weight, the social consequences of following a post-surgical diet (for example, being unable to eat from restaurant menus), and the change in identity that results from significant weight loss (Coulman, Mackichan, Blazeby & Owen-Smith, 2017). But what interrupts the adjustment to the post-surgical life and makes eating control so difficult? The answer might be found in the psychological phenomena of food cravings.

Food cravings are a trigger for maladaptive eating behaviours.

Food cravings – intense desires for specific foods or food groups - have long been implicated in the development of obesity (Schlundt, Verts, Sbrocco, Pope-Cordle & Hill, 1993), disordered eating patterns such as binge eating (Gendall, Joyce, Sullivan & Bulik, 1998), and drop out from weight loss programmes (Sitton, 1991). Sitton (1991) found that dieters who craved carbohydrates were almost three times more likely than people who did not experience cravings to drop out during the first month of a prescribed high-protein diet. Within the population of people with obesity, experiences of food cravings were associated with a greater number of failed weight loss attempts (Fabbricatore, Imperitori, Contardi, Tamburello & Innamorati, 2013).

In people who have had bariatric surgery, initial follow-up data suggests a decrease in food cravings (Crowley et al., 2012; Pepino, Stein, Eagon & Klein, 2014), but a longer-term study suggest that 47% of post-surgical patients still experienced strong food cravings up to five years after surgery (Harbottle, 2011). This is consistent with observations that, whilst bariatric surgery certainly helps clients short-term, the effectiveness is not always sustained over time. Food cravings that lead to eating are associated with guilt and shame (Macdiarmid & Heatherington, 1995) and higher

levels of guilt from cravings predict less weight loss six months after bariatric surgery (Crowley et al., 2012). The experience of food craving in people living with bariatric surgery is understudied but there is some evidence that food cravings differ after surgery. Guthrie, Tetley & Hill's (2014) small study began to investigate the phenomenology of food cravings in post-surgical patients in greater detail, suggesting that bariatric patients reported stronger and more frequent cravings than healthy weight controls one year after surgery, and that savoury foods were the most commonly craved food group in this population over chocolate and sweet foods. However, this was a small study of only 21 bariatric patients so a comparison of surgical types was difficult. Similarly, Leahey et al. (2011) showed that bariatric surgery appeared to reduce food cravings for sweet and fast food within the first six months, but that cravings remained more frequent than experienced by a healthy weight control group. There was no comparison of surgical type in this study. Subsequently, more data are needed to gain a clearer picture of craving experiences in people who have undergone bariatric surgery, including experiences of people who have lived with their surgery for longer, and of how craving experiences are affected by surgical type. As we acknowledge the significance of food cravings in relation to binge eating or other maladaptive eating patterns in the post-surgical population, it is important to consider what is meant by "food cravings" more generally.

Craving

A craving is described as an "*emotionally charged mental state where an urge or desire to engage in a particular behaviour is maintained in focal attenti*on" (May, Andrade, Panabokke & Kavanagh, 2010). Craving has long been implicated in addictions to alcohol, nicotine, caffeine and other psychoactive substances. In these fields, cravings are often narrowly defined in terms of brain biochemistry – i.e. that

receptors that are used to being stimulated by a substance “cry out” for more when starved of their substance by producing a craving experience. The craving is fulfilled, creating a positive reinforcement loop of pleasure and relief. Thus, cravings are a trigger for relapse into addiction, reinforced over and over with every fulfilment. Developing control of cravings forms a major part of addressing addiction. For example, in the treatment of heroin addiction medications such as methadone reduce the bodily craving for heroin by providing a controlled dose of opiates. Similar techniques are used by cigarette smokers who attempt to break their habit by using nicotine replacement patches, tablets or gum. However, long-term follow-up of methadone programmes show that 30 – 40% of patients continue to use illicit narcotics (Garcia-Portilla, Bobes-Bascaran, Bascaran, Saiz & Bobes, 2014) and not all users of nicotine replacement manage to kick their cigarette habits (Cepeda-Bonita, Reynoso & Erath, 2004), thus the theory is insufficient.

This simple biochemical account of craving does not consider the person’s own experience of the craving and how cognitive, emotional and behavioural antecedents and responses may modify the craving experience. Like many other adults, I am addicted to caffeine and when I arrive at my desk in the morning, I am seized by an all-consuming need for caffeine. I open my emails but cannot concentrate, my mind occupied by thoughts of the dark colour (visual imagery), the strong smell (olfactory imagery), imagining the bitter taste (gustatory imagery) and the feeling of a warm mug in my hands (tactile imagery). Eventually I leave the desk in hunt of a kitchen, planning as I go whether I want tea or coffee (and which blend? Which method of preparation?) and, when I take the first couple of sips, the emotional relief of gaining the caffeine is rewarded by a clearer mind and focus on the task ahead. As demonstrated by this simple day-to-day example, craving experiences are more

complex than the neurochemical responses of the brain's chemical pathways, nor are they a Pavlovian response. For that reason, substance misuse interventions combine pharmacological craving control (such as methadone) with psychosocial interventions, including brief psychological interventions and group programmes such as Narcotics Anonymous, because interventions that consider the psychosocial components of addiction and craving result in better outcomes (NICE, 2007).

Bringing together the biological, cognitive and emotional processes of craving, Kavanagh, Andrade and May (2004) developed the Elaborate Intrusion (EI) Theory of Desires (Figure 1). Key to this theory is the production of emotive, mental imagery of the craved substance. Images can occur because of a combination of a number of different internal or external triggers including visual cues or memories of the substance, or physiological deficit. These images highlight the pleasurable aspects of the craved substance but also draw attention to the lack of the substance in the present, which is fed by the physiological deficit of the substance in the receptors and biological pathways. Thoughts related to the craved substance bring pleasure and encourage more elaborate thoughts of the substance. The authors note that this "*causes a vicious circle of desire, imagery, and planning to satisfy the desire, followed by greater articulation of the imagery*" (page 448). Kavanagh et al (2004) theorised that this vicious cycle of cognitive processing of the craving would impair performance on other cognitive tasks, resulting in the craving being all-consuming and persuasive, especially as satisfying the craving is rewarded by restored cognitive performance. However, the influence of imagery in the craving experience also provides the possibility to reduce or control cravings by providing alternative cognitive tasks. This has been demonstrated in several experiments by the research team responsible for the EI theory of craving and others. For example, that nicotine cravings could be

supressed by engaging participants in visuospatial tasks but not auditory imagery tasks (May, Andrade, Panabokke & Kavanagh, 2010) and cigarette cravings could be reduced via attentional control tasks (May, Andrade, Willoughby & Brown, 2012).

Food cravings

Much of the cravings research has focused on alcohol and drug cravings affecting the subset of the population with drug and alcohol addictions. However, food cravings are far more commonplace; experienced no matter what weight a person is, or whether a person is dieting or not (Hill & Heaton-Brown, 1994). In a sample of 101 adult women, around 60% reported ever having a food craving (of whom 85% said they had experienced a food craving in the last three months; Gendall, Joyce & Sullivan, 1997). Within the general population the most commonly craved food is chocolate, which accounts for around half of all food cravings (Weingarten & Elston, 1991; Hill & Heaton-Brown, 1994; Gendall et al., 1997), followed by sweet foods such as cakes, biscuits and desserts, and savoury snack foods such as crisps and takeaway foods.

Drawing parallels with early understanding of narcotic cravings, food craving was originally viewed as a simple reaction to restriction of food – stop eating a desired food and you will start to crave it. This theory of craving originated in the seminal Minnesota starvation experiment of the 1940s, in which healthy male volunteers were subjected to a starvation diet. As they became emaciated, the volunteers began to become preoccupied with the thought of food, describing visions of food and dreaming of eating during sleep (Keys, Brožek, Henschel, Mickelsen, & Taylor, 1950). Specific food cravings were thought to occur if the body was deficient in a certain nutrient in order prompt consumption and to restore nutritional balance. For example, the discovery of scurvy (vitamin-C deficiency) in the eighteenth century was

the result of sailors reporting cravings for citrus fruits (which are abundant in vitamin-C). This theory is also useful in explaining Pica (the condition in which a person craves non-food substances such as clay, chalk and soil), which is associated with iron and zinc deficiencies (Miao, Young & Golden, 2015).

If this theory true, then dieters who are restricting their eating would be expected to experience more cravings than non-dieters. However, evidence for this theory is mixed. For example, a survey of Canadian students showed no difference in the frequency of food cravings between dieters and non-dieters (Weingarten & Elston, 1991), nor was there an association between dietary restraint and craving frequency in a cross-sectional study of British women (Hill, Weaver & Blundell, 1991). Conversely, meta-analysis of eight studies of people with obesity on a VLCD showed reduced cravings across all food groups (Kahathaduwa, Binks, Martin & Dawson, 2017), but a more in depth analysis of a separate VLCD study showed the reduction in cravings was especially pronounced for the foods allowed on the diet (Harvey, Wing & Mullen, 1993). However, in a more nuanced study, women who were dieting to lose weight experienced more food cravings than non-dieters, and people who were watching their weight, but were not actively trying to lose weight had an intermediate number of food cravings. In this study, food cravings were more likely to be for specific foods which the participant was actively restricting (Massey & Hill, 2012). Hunger, however, is not necessary for craving (Hill, 2007), and small portions of craved foods quell cravings as much as large portions, without satisfying hunger (van Kleef, Shimizu & Wansink, 2013). Certainly, nutrient deficit and food restriction alone is not a satisfactory explanation of food craving.

A second approach to conceptualise food cravings is as food cue reactivity*: "a conditioned response to food that is frequently accompanied by increased salivation,*

physiological arousal and neural activity in regions such as the ventral striatum" (Boswell & Kober, 2016). As discussed earlier, the obesogenic environment in which the abundance of food advertisements and the ready availability of foods act as cues to overeating, and thus lead to weight gain. Indeed, recent research suggests that people exposed to a high number of fast-food outlets at home, work and during their commute consumed more fast-foods, had higher BMIs and were more likely to have obesity (Burgoine, Forouhi, Griffin, Wareham & Monsivais, 2014). This theory has its roots in early learning theory when Ivan Pavlov was able to induce salivation in his dogs by ringing a bell due to the learnt pairing (classical conditioning) of the bell with the presentation of food. More recent studies have demonstrated that humans can also be reliably classically conditioned to experience cravings on the presentation of a food cue (Cornell, Rodin & Weingarten, 1989; Federoff, Polivy & Herman, 1997). Kahathaduwa et al (2017) suggest that food cravings are a learnt response between eating a particular food, the pleasure of eating and with certain environment and social contexts (for example, associating cakes with celebrations). The authors suggest that the decrease in food cravings experienced by people on VLCD is due to the extinguishing of the learnt associations between food and stimuli. People on VLCD continue to be exposed to the environments, social occasions and triggers for eating, but the strict diet ensures they cannot fulfil their usual learnt response to eat and derive positive affect from eating. Meta-analysis of 45 studies of food cue reactivity and craving demonstrated that visual food cues (such as pictures and videos of food) were similar in effect size to real food exposure, and much stronger than other sensory cues (olfactory). Cue exposure and the experience of craving significantly influenced eating behaviour and weight gain with a medium effect size. However, there was no association with BMI or dietary restraint (Boswell & Kober, 2016).

Interventions to reduce food cue reactivity developed from treatments for obsessive-compulsive disorder, a condition in which a person has an overwhelming desire to complete a ritual in response to a troubling thought. The relief associated with the completion of the ritual and the reduction in thoughts reinforces the association between the cue and the response. Response-prevention procedures teach the individual techniques to inhibit these learnt and compulsive responses to a cue in order to "unlearn" the association. Experimentally, Lawrence, Verbruggen, Morrison, Adam & Chambers (2015) showed that computer-based training in which participants learnt to inhibit their motor responses to target foods resulted in lower food intake of the target food when presented with a selection of different foods. Moreover, clinical intervention work with people diagnosed with binge-eating disorder demonstrates the efficacy of response-prevention procedures to reduce binging (Jansen, 1998). After successful testing of response-inhibition based protocols to reduce food intake and increase weight loss within the laboratory setting (Lawrence et al., 2015), researchers at Cardiff University are currently developing the *Restrain* mobile phone app to investigate whether response-inhibition exercises can help people with obesity to lose weight. The app will be available to download by the general public in Autumn 2018.

Certainly, food craving is a more complex phenomenon than originally conceptualised in the drug and alcohol fields of research. Hill (2007) described food cravings as the product of a complex interaction of a number of biological and psychological factors; with research showing that the frequency and content of food cravings vary by factors such as gender, age and cultural background. For example, food cravings decline in frequency and variety in older age (Pelchat, 1997) and women are more likely to crave chocolate than men (Osman & Sobal, 2006). In terms of cultural differences, Egyptian adults were more likely to crave savoury over sweet

foods, and Japanese adults craved national foods such as sushi and rice alongside Western savoury foods such as chips (Komatsu, 2008). Partially, this may be due to the availability of foods and cue-exposure, but also due to the cultural messages about foods. For example, in the United States of America, 91% of women report chocolate cravings compared to only 59% of men. In Spain however, this gender discrepancy is smaller: 90% of women and 79% of men report chocolate cravings. The authors suggest this is because American culture reinforces the idea of female chocolate cravings more predominantly than in Spanish culture (Osman & Sobal, 2006). Finally, craving is influenced by mood, with lower mood implicated in increased cravings in dieters (Hill et al, 1991) and in women with bulimia nervosa (Waters, Hill & Waller, 2001). Christensen and Pettijohn (2001) found that carbohydrate cravers reported feeling distressed prior to cravings, but consumption of carbohydrates assuaged their mood – feeling happy, calm and satisfied after. On the other hand, protein cravers were more likely to feel anxious and hungry prior to craving, and eating their craved food made them more happy and energetic. Participants who craved sweet carbohydrates had a particularly strong correlation between the intensity of their craving and the effect on their mood. The authors suggested that food may be a way of "self-medicating" negative moods – either due to the nutrient make-up of the food, because of other emotional associations with food, or a combination of both.

Elaborated intrusion theory of food cravings

Akin to drug and alcohol cravings, the EI theory of desires can be used to bring together the complex web of cognitive and emotional processes underlying food cravings, as outlined in May, Andrade, Kavanagh and Hetherington (2012). This framework (Figure 1) explains that food cravings consist of the elaboration of thoughts about food which have been triggered by a mixture external cues (for

example, seeing or smelling the desired food) and internal cues (such as memories of the food, emotional triggers, or changes to hunger hormones in the biochemical pathways). Because these thoughts and images are pleasurable, they become more elaborate, including planning to acquire and consume the desired food. However, if the desire cannot be satisfied due to e.g. dietary restriction of the food, lack of access to the food, the experience becomes unpleasant. Mood drops, and more pleasurable thoughts, images and memories are stimulated about the food to ease the mood. However, this leads to a vicious cycle, as the more images of food are produced, the more the person realises the absence of that food. Eventually, the person breaks the cycle via consumption of the desired food or by some sort of redirection or distraction, resulting in relief and/or pleasure. Research has revealed that the intensity of the food craving is positively correlated with the vividness of the mental imagery experienced (Tiggemann & Kemps, 2005).

Assessment of food cravings

One of the challenges to studying food cravings is the difficulty in developing a satisfactory way of capturing such a complex, internal and personal experience. Several different approaches have arisen to capture food cravings. Whilst biological measures have been tried with limited success (e.g. measurement of the secretion of saliva), the most common method is self-report through standardised questionnaires. The commonly used Food Craving Inventory (FCI; White, Whisenhunt, Williamson, Greenway & Netemeyer, 2002) asks participants to rate their subjective craving frequency for 47 commonly craved foods. However, cultural variation in foods craved means the FCI has required multiple versions to be developed for different cultural

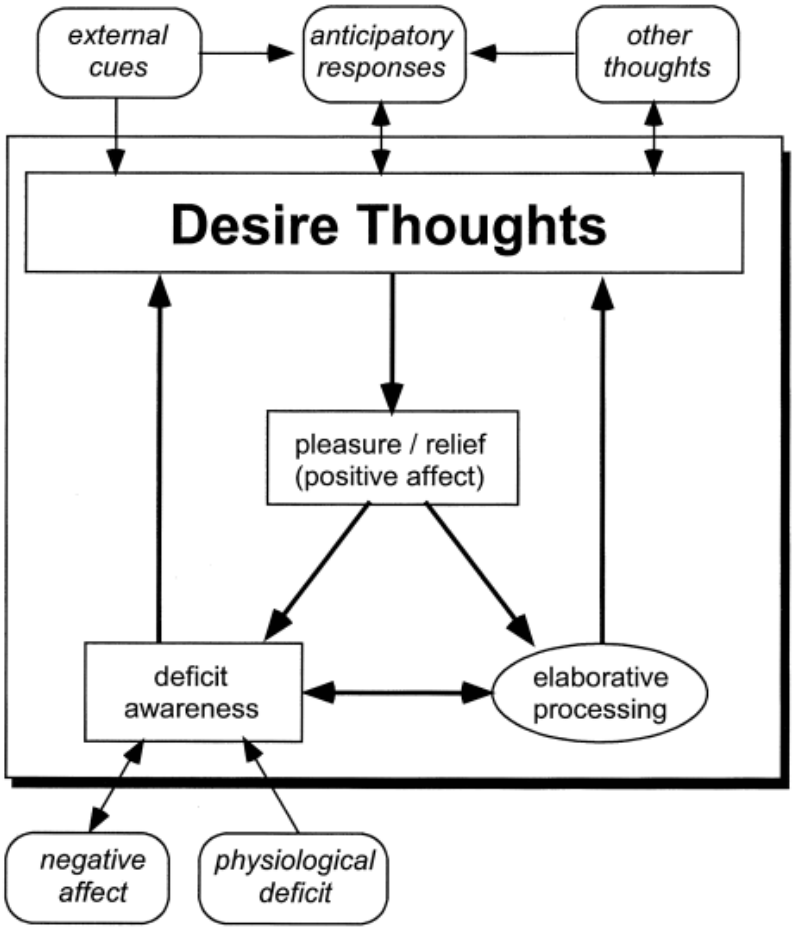

Figure 1. The Elaborated Intrusion Theory of Desires, reproduced from Kavanagh, Andrade & May (2004). Antecedents of craving are shown in the rounded rectangles whilst cognitive products of craving are shown in rectangles. Processing includes construction and elaboration of images (shown in oval). The consequences of craving are not shown.

groups (e.g. FCI-UK; Nicholls & Hulbert-Williams, 2013). This method also misses out vital information about the cognitive and emotional aspect of the craving. Better is the Food Craving Questionnaire – a questionnaire assessment that covers not only the details of what was craved, but the mood, hunger and the reward associated with the food craved (Cepeda-Benito, Gleaves, Fernandez, Vila & Reynoso, 2000). Qualitative methods have also been used, such as interviews and freely-written accounts of food craving experiences. These descriptive accounts allow for greater detail and complexity to emerge about the character of the food craving. However, each of these approaches is limited to being a one-off, retrospective, generalised

account of food craving experience, which may or may not be completed with reference to a lived craving experience.

Rather than using questionnaires to give a general overview of cravings, researchers have developed protocols to investigate specific and immediate food cravings experiences. Three major methodologies have evolved: ecological momentary assessment (EMA), experimental methods and critical incident analysis (CIA). EMA protocols require participants to provide data (e.g. by answering a questionnaire) at time-points determined by the researcher, which can be prompted by a text message, paging device, smartphone, or similar. For example, the participant may complete the questionnaire at 2-hourly intervals throughout a day. Alternatively, the participant is provided with random prompts. Previous studies have successfully used EMA to investigate eating behaviour; for example Goldschmidt et al (2014) used an EMA protocol to examine eating behaviour in adults with BMIs in the obese ranges, providing participants with PDA devices which could prompt participants to enter data at semi-random time points; and a similar strategy was used by Grenard et al (2013) to investigate snacking behaviour in adolescents.

An alternative method is to use experimental methods to induce cravings which can be followed immediately by questionnaire data collection. This allows for the controlled, contemporaneous collection of the experience of a food craving. For example, Hamilton, Fawson, May, Andrade and Kavanagh (2013) asked students to abstain from eating for nine to twelve hours and then seated them in front of several food items to complete a number of eating questionnaires and respond to a series of questions about their usual eating habits and favourite foods in order to induce a food craving which could then be measured. Similarly, Kemps and Tiggemann (2005) asked their student participants to recall their last experience of a food craving in as

much detail as possible, think about their favourite food and then imagine they were eating it to induce a state of food craving. However, although well controlled and timely, these experimental methodologies compromised the ecological validity that make EMA techniques so appealing. It could be argued that the food craving induced by the protocol is not the same as a "true" food craving that arises naturally and spontaneously. It is also more suitable for participants who can commit to the time involved in an experimental procedure and thus is mostly used with students.

The final method, CIA, allows for the collection of contemporaneous, phenomenological data that arises from authentic food cravings in the participant's day-to-day life. CIA protocols (first described by Flanagan, 1954) treat each food craving experience as a "critical incident". When a critical incident occurs, the participant responds by completing a survey detailing their experience as close to the critical incident as is feasibly possible. Although CIA relies on participants to notice their food craving and remember to complete the questionnaire without external prompting, it has been used successfully by previous researchers in this field (Hill & Heaton-Brown, 1994; Massey & Hill, 2012; similar protocol employed by Jenkins & Tapper, 2013) and in the paper which serves as a starting point for this project (Guthrie et al., 2014). The Food Craving Record (developed by Hill & Heaton-Brown, 1994) is a 18-item questionnaire that is designed to be used in direct response to a food craving within CIA methodology that details the environmental context, mood state, hunger, intensity, resistibility and behaviour associated with a food craving. By completing this measure every time a food craving occurs over a period of days or weeks, a more detailed and specific account of real-life food cravings can emerge.

Using smartphone technology to examine eating behaviour

Past research projects into food cravings using CIA methodology have required participants to fill out paper-and-pencil questionnaires in a timely manner in response to cravings (e.g. Guthrie et al., 2014). Therefore this methodology has relied on the participant carrying around copies of the questionnaires throughout their day-to-day life for the study duration. On the other hand, EMA research has successfully utilised portable, digital technology to investigate eating behaviour (Goldschmidt et al., 2014; Grenard et al., 2013). Berkman, Giuliana and Pruitt (2014) used both paper and PDA methods concurrently in their EMA study of food craving and food intake and compared their data quality as part of the data analysis. They concluded that technology was a superior research method to paper as it reduced the time between the incident and recording of the information regarding the event and increased the response rate, although this is difficult to determine.

We are part of an increasingly digitised and paperless society. In the decade since the launch of the touchscreen smartphone, and five years since the launch of 4G mobile internet, smartphone and tablet devices have become a ubiquitous part of modern life. The Communication Market Report 2016 conducted by Ofcom estimated that 71% of adults in the United Kingdom owned a smartphone. A Deloitte survey from the same year put this figure ten percent higher (81%), and reported that the greatest users are 16-24 year olds, 91% of whom own a smartphone device (Deloitte, 2016). However, the fastest recent growth in ownership has been in the 55-65 age bracket where ownership has soared from 19% in 2012 to over 50% in 2015 (Ofcom, 2015). In addition to smartphones, the 2015 Ofcom report also estimated that 54% households in the UK own a tablet device. To make participation in this study as unobtrusive as possible to the participant, and to help maximise the fidelity to the CIA

model, this study borrows from the EMA literature and capitalise on omnipresence of smartphones and tablets by creating computer, mobile and tablet friendly copies of the research materials.

The clinical relevance of investigating food cravings in post-surgical bariatric patients

As in drug and alcohol addiction, the EI theory of food cravings introduces the possibility of interrupting the vicious cognitive-emotional cycle of food cravings by introducing an alternative cognitive task. In contrast to the addictive substances literature, evidence related to food cravings is in short supply. However, there is some promising research that applies the EI theory of desire to direct possible interventions into food craving.

Novel visuospatial tasks can interrupt the vicious cycle of food cravings

Kemps, Tiggemann and colleagues have conducted several lab-based experiments with students based on the EI theory of food craving. These have shown that introducing visuo-spatial tasks after inducing a food craving can reduce or suppress the cravings for food (Kemps & Tiggemann, 2007; Kemps, Tiggemann, Woods & Soekoy, 2004) or coffee (Kemps & Tiggemann, 2009). Similarly, May and colleagues used attentional control tasks to reduce intrusive thoughts about snack foods (May, Andrade, Batey, Berry & Kavanagh, 2010). Another study has used a plasticine modelling task to reduce food cravings in participants (Andrade, Pears, May & Kavanagh, 2012). However, although this information has been useful experimentally, it is unrealistic to suggest that people struggling with food cravings will be able to engage in these sorts of experimental tasks into their day-to-day life. So, to have real world applicability, the tasks must be designed differently.

Mental imagery tasks can reduce food cravings

The latest wave of cognitive behavioural therapies includes mindfulness-meditation-based programmes that have arisen from Buddhist psychology (Acceptance and Commitment Therapy [ACT] and Compassion-Focused Therapy) utilise mental imagery, visualisation and mindfulness meditation-based techniques as part of their practice. As visual mental imagery is a core part of the craving experience, and using competing cognitive tasks can interrupt food craving processes, it seems logical to extend these third-wave psychological techniques to help clients directly control food cravings.

Hamilton, Fawson, May, Andrade and Kavanagh (2013) asked students to abstain from eating for nine to twelve hours and then seated them in front of several food items, completed a number of eating questionnaires and asked a series of questions about their usual eating habits and favourite foods to induce a food craving. Participants were randomly allocated to two ACT-based interventions: either a body scan guided meditation (in which participants pay attention to particular body parts in turn), a guided imagery exercise (asking participants to imagine a forest walk using multiple senses), or to the control condition in which the participants were told to think of "anything or nothing at all" and to "let their mind wander wherever it will go." The results showed that cravings measures increased in the control group who let their mind wander freely, but remained constant for those with the experimental tasks. The authors suggested that meditation and imagery tasks could be helpful for people who are trying to resist food cravings. However, this study was conducted in a controlled experimental environment and it could be argued that the utility of mindfulness techniques would be reduced in the day-to-day life of the participants.

Jenkins & Tapper (2013) conducted a more naturalistic experiment with participants who were actively trying to cut down their consumption of chocolate. The participants were taught one of two techniques from ACT. Participants either employed a cognitive defusion technique (that helps someone to see themselves as separate and distinct from their mental activity), an acceptance technique (that promotes the acceptance of mental activity without need to change or control their presence), or a (control) relaxation technique to use if they experienced a chocolate craving. The participants were then given a bag of chocolate to carry with them and asked to use their strategy if they noticed a chocolate craving. The results showed that participants using cognitive defusion techniques ate significantly less chocolate not only from the bag, but elsewhere in their diet, than the acceptance and control groups. The acceptance technique showed no benefits over the control procedure. Notably however, these studies have recruited non-clinical student populations who have not reported difficulty with weight management or dealing with food cravings.

These techniques have been successfully applied in individual and group psychotherapy as clinical interventions for binge eating and emotional eating (Katterman, Kleinman, Hood, Nackers & Corsica, 2014; Godfrey, Gallo & Afari, 2015), and there is some published clinical research in which food cravings specifically have been targeted with a clinical intervention. Alberts, Mulkens, Smeets & Thewissen (2010) successfully used mindfulness-based interventions to reduce food cravings in a group of adults with overweight and obese BMIs in the Netherlands; measuring food cravings on the General Food Craving Questionnaire – Trait (Nijs, Franken & Muris, 2007). The authors followed-up their initial study with a mindfulness-based group for people with problematic emotional eating or overeating (but excluded participants with diagnoses of anorexia or bulimia nervosa)

and measured food cravings before and after the group. Participants on the programme significantly reduced their BMI over the course of the group and showed improved scores on a number of disordered eating questionnaires and reduced cravings (Alberts, Thewissen & Raes, 2012). However, in both these studies the participants were not asked to record the specific details of food cravings experiences over the course of the group, only to complete a generic measure before and after the interventions. As a result, more detailed information about how the intervention affected food cravings is lost.

This promising research suggests that meditation, mindfulness-based and imagery exercises could be a useful avenue for intervention for people who are struggling with food cravings after a bariatric procedure. However, the phenomenological experience of food cravings and mental imagery within the bariatric-surgery population, and their relationship to eating remains relatively unstudied. These data could provide the essential foundations for developing an intervention protocol that is targeted to the specific characteristics of food cravings and maladaptive eating in the post-surgical population.

Summary of the literature

Obesity is one of the largest global health challenges and in instances of life-threatening obesity, bariatric surgery is the key intervention. Although bariatric surgery can result in substantial weight loss in the year post-surgery, long term outcomes are not so positive. A proportion of people who have received bariatric surgery will regain the weight lost via the surgery. Key to the pre-surgical obesity and the post-surgical weight gain is maladaptive eating which can be triggered by food cravings. Food cravings are understood as psychological phenomena consisting of

intense desires for specific food items. However, whilst commonplace, there is very little research describing the experience of food cravings in people who have received bariatric surgery, and comparing the different forms of bariatric surgery.

Elaborated intrusion theories describe food cravings as an interaction between environmental cues, internal mental imagery, cognitive planning, and affect. Research suggests that the intensity of food cravings is related to the vividness of the mental sensory imagery generated. The imagery elements of food cravings could be a target for therapeutic intervention using techniques such as mindfulness meditation and guided imagery techniques to interrupt food cravings. There is a gap in the literature and an opportunity to enhance existing research by investigating the experience of sensory imagery within food cravings in the post-surgical population. Finally, there is scope to explore relationships between the experience of cravings, imagery, maladaptive eating, mood and the outcomes of bariatric surgery in this patient group. Collecting and analysing these data potentially paves the way to develop psychological interventions to assist people who have struggled to control their eating after bariatric surgery and improve post-operative outcomes.

Research Objectives

This thesis uses CIA to explore experiences of food cravings in people who have received bariatric surgery between 12 months and 10 years previously. The primary and secondary research questions are as follows:

Primary research questions

- What is the frequency of, and what are the phenomenological characteristics of, food cravings in people who have received bariatric surgery?

- Do these characteristics of food cravings differ between patients who have received different types of bariatric surgery?

- How are the characteristics of food cravings related to craving intensity and resistibility?

Secondary research questions

- How are participant traits such eating patterns, disordered eating, mood and use of mental imagery related to:
    a) Surgical type
    b) Whether or not a person experiences food cravings
- How are the characteristics of food craving and participant characteristics including weight change, eating patterns, disordered eating, mood and use of mental imagery related to the intensity and resistibility of food cravings?

METHOD

Design

A cross-sectional, descriptive research design was used. Use of CIA and self-report methods allowed participants to self-define their experience of "food craving" and report contemporaneous and ecologically-valid data.

The study was approved by the East of England – Essex Research Ethics Committee on 10/07/2017 (IRAS reference: 219652, REC reference: 17/EE/0252). The study was also registered with the Research and Innovation department at Leeds Teaching Hospitals NHS Foundation Trust.

Participants

One local NHS bariatric surgery clinic consisting of five surgeons (St James' University Hospital, Leeds Teaching Hospitals NHS Trust) and one local private sector provider consisting of one surgeon (Yorkshire Stomach Surgery Limited) agreed to act as recruitment sites. The private sector provider carried out bariatric surgery for both self-funded patients and those with NHS funding.

The following participant inclusion criteria were applied:

- 18 years or older
- A minimum of 12 months post-surgical bariatric procedure
- Capacity to provide informed consent

Exclusion criteria were:

- Unable to independently complete study questionnaires and assessments

- More than 10 years post-surgical procedure
- Current pregnancy
- Having had more than one type of bariatric procedure e.g. initially opting for LAGB, then having it removed and converted into a RYGB procedure, or having a second surgery to remove a larger portion of the digestive system

Figure 2 shows the movement of participants through the procedure. In total, 702 patients were sent an invitation to join the study (402 NHS, 300 private). Of these, 86 returned a consent form expressing their interest in taking part (57 NHS, 31 private) within the timeframe of the study, representing a 12.3% initial response rate. Four were excluded for not meeting the research criteria, eight declined to take part after discussion with the researcher and 18 did not respond to contact from the researcher. Fifty-six people agreed to take part in the study, but six did not return any data, representing a 10.7% drop out rate. Fifty participants returned data to the study (36 NHS, 12 private; 7 males), of which five were excluded due to incomplete data. Clinical data were requested from the recruitment source for 45 patients, for whom two patients had incomplete clinical records so were excluded. As a result, the total sample was 43 participants (31 NHS, 12 private, 7 males, achieving 86% of the initial recruitment target). Twenty-three participants used the online questionnaires, and 20 submitted paper-and-pencil questionnaires.

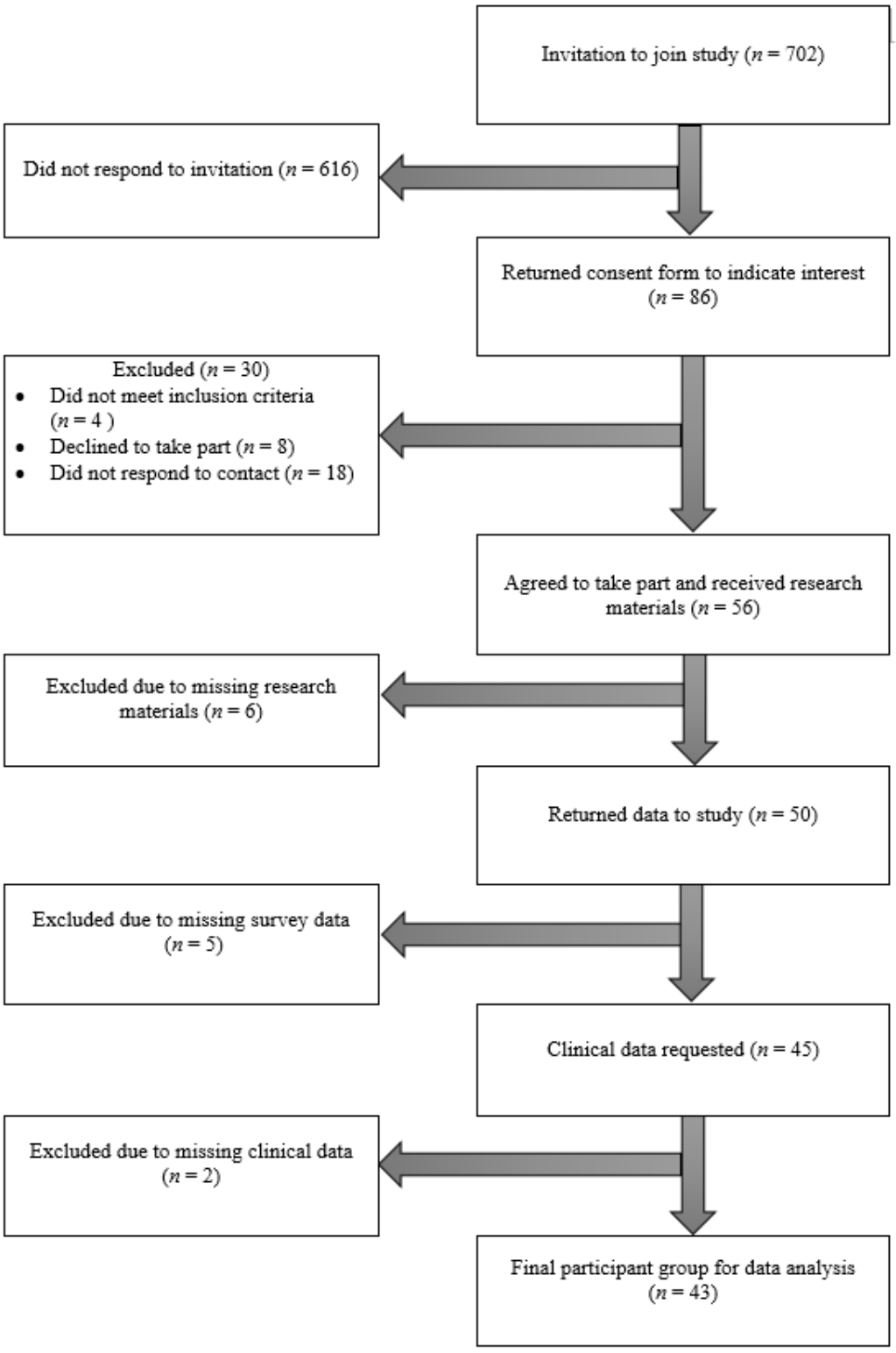

Figure 2. Participant uptake, retention and drop-out from the study procedure.

Measures

Measures were created in two formats: paper and pencil hardcopies, and in web-based format. The web-based questionnaires were created and hosted using Bristol Online Surveys (BOS), which is a secure survey website used frequently by universities and healthcare services. BOS was selected due to a combination of the cost, security and encryption, and the features provided by the programme. The web-based questionnaires were accessible via any internet-enabled device. All measures are included in Appendix A.

Food craving record

Participants filled out the following items in response to a food craving in order to describe their experience:

Food craving record (Hill & Heaton-Brown, 1994).

An adapted version of the craving record captured the main characteristics of food cravings. Nine questions are directed at three key areas: the context of the craving (the time of day, antecedent events), the characteristics of the craving (target of the craving, craving intensity, hunger state, amount to which the craved food is restricted, difficulty to resist) and subsequent behaviour (did the craving lead to an eating episode, if so – what was eaten, how pleasant was the food and how quickly did the craving disappear). Questions regarding mood state were removed for brevity. Eleven-point scales (numbered from 0 – 10, with a descriptor at each pole e.g. 1 meaning not at all to 10 meaning extremely) allowed participants to subjectively rate the magnitude of characteristics of the craving experience. As the food craving record is used as a way to describe a personal, contemporaneous experience, there are no studies of its psychometric properties but it has been used successfully in previous

food craving research (e.g. Guthrie et al., 2014, Massey & Hill., 2012). In the original version of the food craving record, the questions were depicted as visual analogue scales (VAS). VAS are a reliable measure of psychometric properties with good test-retest reliability and correlation with other psychometric questionnaires as shown in Williams, Morlock and Feltner's (2010) evaluation of different assessments of anxiety. As VAS were more difficult to complete using internet-enabled devices than on paper, the VAS were converted to numerical rating scales (NRS) and the participant was requested to tick a discrete numerical rating rather than mark a line. A comparison of the measurement of pain showed a high correlation between scores given on a VAS compared with a NRS (r = 0.94; Bijur, Latimer & Gallagher, 2003), and a systematic review comparing VAS and NRS methods to rate pain intensity demonstrated that scores corresponded across both methods, but there was some evidence of improved compliance with NRS over VAS. (Hjermastad et al., 2011)

Craving Experience Questionnaire – Sensory (CEQ-S, May et al., 2014).

To assess the sensory experience of craving, four additional questions were added to the food craving record from the CEQ-S. The CEQ-S was developed by the researchers who formed the EI model of food craving and captured the vividness of mental imagery in terms of picture, smell, taste and bodily feeling. One question (*"how vividly did you imagine the feeling in your mouth or throat?")* was omitted as it was felt the retained question *"how vividly did you imagine the feeling in your body?"* would suffice to answer the research question. Each question was rated on an eleven-point scale with descriptive anchors at the poles (from "not at all vividly" to "extremely vividly") in the same fashion as the food craving record. The CEQ-S has good internal reliability (α=0.91) and the authors indicated the scales' validity in

comparison to other standardised craving scales. The retention of four out of five questions in the scale is unlikely to compromise validity.

Finally, a free text question at the end of the food craving record form captured any additional information the participant wished to give about their craving experience.

End of day questionnaire

The end of day questionnaire (used in Guthrie et al., 2014) aimed to contextualise food cravings in their ecological environment in terms of mood, eating pattern and eating restriction. It was also used to keep participants engaged in the study when they were not experiencing cravings and could be used to describe the experience of days in which no cravings were experienced in comparison to days which included cravings. It consisted of the eight, eleven-point scales (0-10) with descriptive anchors at the poles ("not at all" and "extremely") and is completed towards the end of each study day. Firstly, participants were asked to rate each of the following six states according to how they felt during that day: anxious, ease of eating control, content, hungry, tense and irritable. If the participant ate as a result of craving, they were asked to state what they ate, how long they waited to eat (in minutes) and asked to complete two further scales regarding the pleasantness of the food, and how quickly the craving dissipated after eating. In the original version of the end of day questionnaire featured VAS but these were converted to NRS as per the food craving record.

Meal Pattern Questionnaire (Bertéus Forslund, Lindroos, Sjöström & Lissner, 2002)

This assessment comprised 24, one-hour time slots covering one twenty-four hour day and followed the end of day questionnaire ratings above. The participant ticked each form of meal eaten during that time in the last 24 hours. Meal types

included: main meal, light meal, snack or drink only. Whilst there are no published metrics on the reliability or validity of this method of meal recording, this questionnaire was chosen as an alternative to a traditional food diary as the meal pattern questionnaire looks at how and when eating occurs, rather than focusing on the nutritional content of meals. It has successfully been used to study the eating behaviour of people with obesity and the authors suggest its simplicity and brevity reduce the likelihood of underreporting in individuals with obesity (Bertéus Forsland, Torgerson, Sjöström & Lindroos, 2005). Finally, a text prompt at the end of the questionnaire reminded participants to complete the food craving record for any craving events that occurred during the day.

Background information questionnaire

Participants filled out a background questionnaire on one occasion before their study week which consisted of the following items:

Background demographic data

Participants provided their name, date of birth, gender and postcode (to allow to identification of medical records), as well as self-reported current weight and height (to calculate current BMI and weight loss since surgery). In addition, pregnancy status, concurrent major health problems and associated medication were requested.

The emotional eating sub-scale from the Three Factor Eating Questionnaire (TFEQ-R18V2; Cappalleri et al, 2009)

The TFEQ-R18V2 is an 18-item measure consisting of three 6-item subscales examining three aspects of eating (emotional eating, uncontrolled eating and restraint) in people with obesity. Only the emotional eating subscale was used which has a good internal reliability within clinical samples (α=0.92; Karlsson, Persson, Sjöström &

Sullivan, 2000). The emotional eating subscale consists of six items rated as "definitely true," "mostly true," "mostly false" or "definitely false." The uncontrolled eating and restraint subscales were not used firstly, for brevity, as the same constructs could be measured using a shorter seven-item questionnaire (i.e. EDE-Q-R).

Grazing Questionnaire (Lane & Szabó, 2013)

This seven-item self-report questionnaire examines grazing behaviour, defined by the authors as "uncontrolled, repetitive eating of small amounts of food." Responses were chosen on a five-point descriptive scale: "Never," "Rarely", "Sometimes," "Most of the time" or "All of the time". According to the authors, the questionnaire has high internal consistency (α=0.92) and the authors report strong test–retest reliability when re-administered within three weeks *(*r = .62, p < .01) and over three weeks later (r = .71, p < .01).

Eating pattern type (Conceiçao et al., 2014)

Five types of eating patterns typical of patients post-surgery have been distinguished and defined in an expert consensus review by Conceição et al (2014): 1) "planned and controlled eating," described as eating small amounts of food through the day, choosing what to eat and controlling the amount eaten; 2) "deliberately overeating" described as repeatedly eating small amounts in order to overeat or dividing large meals into separate courses in order to overeat, 3) "grazing but in control," described as mindlessly eating, or eating in a distracted way, eating whatever is available on the spur of the moment; 4) "grazing but out of control", described as trying to resist foods but going back to eat small or modest amounts, eating what is most tempting in the moment or responding to urges to eat; and finally (subjective) "binge eating" defined as feeling that you cannot stop once eating commences, and

feeling out of control over eating episodes. These patterns were defined in turn and participants chose one to best describe their eating pattern over the past seven days.

Eating Disorder Examination Questionnaire-Revised (EDE-Q-R; Grilo, Henderson, Bell & Crosby, 2013)

The EDE-Q was revised to assess symptomology of clinical eating disorders in bariatric surgery. Participants answered seven items to yield scores on three subscales, each with acceptable internal consistency coefficients: dietary restraint (α=0.82), shape/weight overvaluation (α=0.96), and body dissatisfaction (α=0.69). Objective binge eating was assessed via two of the EDE-Q-R questions which requested participants to state the number of days in the past month they had significantly overeaten, and how many days they had lost control over their eating. According to the authors, the EDE-Q-R has good convergent and discriminant validity when compared to alternative standardised measures.

Spontaneous Use of Imagery Questionnaire (SUIS; Nelis, Holmes, Griffiths & Raes, 2014)

This 12-question scale measures participants' tendency to experience mental visual imagery in everyday life with acceptable reliability and validity. Participants indicated the degree to which each of the situations described their visualisation experience on a 5-point response scale. Within community samples, the internal validity is acceptable (α=0.72), as is the test-retest reliability (r=0.69, p<0.1). The authors also state the SUIS shows acceptable convergent and divergent validity with alternative standardised measures. It has not been used with a bariatric sample.

Short Form Depression Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995)

DASS-21 is a self-report measure of common mood disorders consisting of three subscales – depression, anxiety and stress. Only the depression and anxiety subscales

were included for brevity. The DASS-21 is valid for use in both clinical populations with diagnosed mental health concerns and in non-clinical populations (Antony, Bieling, Cox, Enns & Swinson, 1998). In community samples, the DASS-21 shows good internal reliability for both the depression scale (α=0.82) and the anxiety scale (α=0.90), and it has good divergent and convergent validity when compared to other standardised measures (Henry & Crawford, 2005). The DASS has been employed as a measure of mood in previous studies of food cravings (Guthrie et al., 2014; Smithson & Hill, 2017)

Procedure

Administrative staff from the recruitment clinics identified patients who met the inclusion criteria and sent each eligible patient a recruitment pack containing: an invitation letter, a participant information sheet, a consent form (Appendix B) and a postage-paid return envelope. Potential participants were asked to read the information sheet, then sign and return the consent form to the researcher if they were interested in taking part. NHS clinic patients who did not return a consent form within six weeks were sent a reminder letter. However, resources were not available to send second invitations to the private clinic patients.

Individuals who returned a consent form were contacted by telephone, screened for eligibility and received a brief explanation outline of the study procedure. The participant selected whether they would prefer to complete the study via paper-and-pencil or via the web-based questionnaires using any internet-enabled device. Participants were asked to select the method which would suit their lifestyle best to allow them to fill out the surveys as accurately as possible.

Participants who opted for the paper-and-pencil method received a research pack in the post consisting of: a cover letter containing a reminder of the study instructions (Appendix B) and the researcher contact information, a background information questionnaire, seven end of day questionnaires, and five food craving records, with a postage-paid return envelope. A telephone appointment with the participant was scheduled to discuss the study procedure further after the materials had been received to allow the participant to familiarise themselves with the materials being discussed over the phone. Participants were asked to contact the researcher if they required additional food craving records. Those who opted for the web-based method received an email containing: weblinks to each of the online questionnaires, a reminder of the study instructions and contact information for the researcher. They were asked to open the links to check they could access the website, and assisted with accessing the website on their internet-enabled devices if necessary. All participants were provided instructions on how to complete the materials, then asked to describe how they intended to complete the materials to confirm their understanding to the researcher.

To complete the study, all participants were instructed to first fill out the background information questionnaires, and then to nominate a seven-day study week in which they monitored aspects of their mood, eating habits and food craving experiences. During these seven days, if the participant experienced a food craving, they completed a food craving record as soon as possible after the craving. At the end of each day, the participant completed an end of day questionnaire. For the purposes of the study, a food craving was defined as *"an intense desire for a specific food or food group"*.

Participants were contacted by text or email on either day three or four of the study to discuss any issues and encourage continued participation. Participants were contacted on day seven or day eight to thank the participant for their participation, remind the participant of their right to withdraw their data, and to prompt participants using the paper questionnaires to return them to the researcher. Finally, clinical data about patients who completed the study were obtained from the relevant clinic administrator.

Reasonable adjustments

Reasonable adjustments were offered to ensure inclusivity of participants with additional needs could access the study. Participation of participants with additional needs was considered on an individual basis; but reasonable adjustments that could be accommodated included providing larger font copies of the questionnaires for participants with a visual impairment, or providing a face-to-face meeting to explain the study procedure and materials. Two participants opted to meet for a face-to-face meeting due to difficulty hearing on the telephone.

Data analysis

Measures were scored according to their individual manuals. Participants were included in the study as long as their background information measures were completed satisfactorily to ensure validity as per the measure's manual, they returned end-of-day questionnaires for at least six days of the study week, and the clinic could confirm their surgical and weight history (shown in figure 2). Data were analysed using IBM SPSS Statistics 23 and R (R Core Team, 2018). Missing data was defined as missing in SPSS and R. Data were checked for outliers, and checked for normality and distribution using histograms.

Primary research questions

The primary research questions were: to describe the characteristics and frequency of food cravings; to establish any differences in characteristics of food cravings between surgical groups and finally; to establish what characteristics of food craving influence craving intensity and resistibility. To address these questions, firstly data from the food craving record was summarised using descriptive statistics. Secondly, comparison of means tests were conducted to compare to two key surgical types (gastric banding vs restructuring surgeries) on each key factor. Normal data was tested using independent measures t-tests, repeated measures t-tests and non-normal data tested using Mann-Whitney U-tests.

Next, to provide a phenomenological description of the context of food cravings, the end of day data were summarised and key descriptive information was reported. End of day data from participants who did not report any cravings were excluded. R (R Core Team, 2018) was used to perform restricted maximum likelihood linear mixed-effects analysis (lme4 package, Bates, Maechler, Bolker, & Walker, 2012) to determine whether the outcome of the day (whether a craving was experienced or not) was related to the experience of the day and surgical type. Participant ID was included as a random effect. One measured variable relating to the experience of the day (e.g. anxiety) was tested as a fixed effect in turn alongside surgical type. The analysis was repeated for each variable. Variables with t-values over two were considered strongly related to the occurrence of a craving, then converted to *p*-values.

Finally, two key characteristics of food cravings were explored: firstly, the intensity of a food craving (calculated from the sum of the strength of the food craving plus the difficulty to resist of the food craving), and secondly, the outcome of the

craving (fulfilled or resisted). This was done by creating decision trees in SPSS which provided visual representations of the data collected by the food craving record. Decision trees classify data into groups to predict values of a dependent (target) variable based on values of independent (predictor) variables. Trees were created using the CHAID growing algorithm with p = 95%. The CHAID algorithm was used as it is non-parametric, can manage both continuous and categorical variables, and it produces non-binary trees (where parents nodes can split in to more than two child nodes to create the best fit). To ensure a manageable tree was produced, the minimum number of cases in the parent node was restricted to 25 responses, and child nodes required a minimum of 10 responses. The trees were restricted to a maximum of three levels. This prevents the tree splitting the data into groups containing very small amounts of data. Two trees were created. For the first tree, craving intensity was included as a continuous target variable, and for the second tree, craving resistibility was included as a binary categorical target variable (resisted or fulfilled). The following variables were included as possible predictor variables: craving antecedent, time of craving, target of food craving, craving intensity, individual imaginary sensory qualities of food craving (picture, smell, taste, feeling), a sum score of all imaginary sensory qualities, and surgical type.

Secondary research questions

To first establish how participants traits (eating patterns, disordered eating, mood and use of mental imagery) are related to surgical type and whether or not a person experiences food cravings, data from the background information questionnaire was summarised using descriptive statistics. Secondly, comparison of means tests were conducted to compare to two key surgical types (gastric banding vs restructuring surgeries) and two key craving groups. Participants who reported a

craving during the craving week (called the “craving group”) were compared to the group of participants who did not report a food craving during the study period (called the “non-craving group”). Normal data was tested using independent measures t-tests, repeated measures t-tests and non-normal data tested using Mann-Whitney U-tests.

Next, data were analysed to explore associations between the key characteristics of food cravings (intensity and resistibility) and participant characteristics (age, current weight, percentage weight-loss, scores on standardised measures of mood and eating behaviour, and everyday use of mental imagery). R (R Core Team, 2018) was used to perform a restricted maximum likelihood linear mixed-effects analysis (lme4 package, Bates, Maechler, Bolker, & Walker, 2012) of the relationship between intensity of craving and all variables measured by the food craving record and background information questionnaire. The participant ID was included as a random effect to account for the interdependence of multiple responses from the same participant. A backward stepwise process was used, first testing all variables as fixed effects, then removing variables which did not contribute to the model until a parsimonious model was reached. T-values of approximately two were considered a good fit in the model and included, then converted to *p*-values using conversion tables. Secondly, R was used to perform a generalised linear mixed-model analysis (with Laplace approximation; glmermod package, Bates, Maechler, Bolker, & Walker, 2012) of the relationship between the outcome of the craving (resisted or fulfilled) and variables on the food craving record and personal characteristics. A backwards stepwise process was used as before, entering all variables from the food craving record and the background information questionnaire were added to the model as fixed effects, and the participant ID as a random effect then removing fixed effects that did not contribute to find a parsimonious model. *P*-values that represented

significance of 90% or higher were included in the model. Odds ratios were calculated. Pearson correlations between key characteristics of food craving and participant characteristics can be found in Appendix C.

RESULTS

Participant characteristics

Forty-three participants completed the study (84% female). Eight participants had received a LABG (18%) and 35 participants had received a restructuring surgery (29 RnY (67%), 5 sleeve gastrectomy (11%), 1 duodenal switch (0.02%). Key demographic information including weight and BMI history of all participants and those in either surgical group are shown in Table 1.

Table 6

Demographic, weight and BMI history of participants (mean (S.E.) range); compared according to surgical type.

	Total sample	LAGB group	Restructuring surgery group	t(41)	*p*
n	43	8	35		
Age	52.14 (1.60) 30 - 72	55.75 (3.00) 45 – 71	51.31 (1.83) 30 - 72	1.08	0.29
Months since surgery	62.56 (4.11) 14 – 135	56.25 (13.51) 19 - 135	64.00 (4.09) 14 - 108	0.73	0.47
Current weight (kg)	91.71 (3.21) 67.70 - 170	93.81 (9.57) 67.70 – 141.00	91.23 (3.35) 68.00 – 170.00	0.31	0.76
Current BMI (kg/m^2)	32.75 (1.01) 24.36 - 58.2	32.70 (2.72) 25.05 – 44.98	32.80 (1.10) 24.36 – 58.82	0.02	0.93
Pre-surgical weight (kg)	137.94 (3.70) 86.60 – 191.60	122.20 (10.71) 86.60– 182.20	141.53 (3.65) 102.00 – 191.60	2.12	**0.04**
Pre-surgical BMI (kg/m^2)	49.52 (1.36) 34.22 – 76.29	42.71 (2.81) 34.22 – 56.23	51.08 (1.43) 36.24 – 76.29	2.55	**<0.01**
Weight loss (kg)	46.30 (2.71) 18.20 – 99.26	28.64 (3.19) 18.20 – 41.20	50.34 (2.85) 21.60 – 99.326	3.51	**<0.01**
Weight loss (%)	33.24 (1.50) 11.27 – 55.14	23.80 (2.36) 12.28 – 35.32	35.40 (1.55) 11.27 – 55.14	3.37	**<0.01**
BMI change	16.77 (1.06) 6.30 – 38.39	10.01 (1.01) 6.30 – 13.68	18.32 (1.14) 7.47 – 38.39	3.40	**<0.01**

All participants had a lower weight and BMI compared to their pre-surgical weight. The LAGB group had a significantly lower pre-operative weight and pre-operative BMI than the restructuring surgery group. The LAGB group also showed smaller weight changes from post-surgery, a significantly lower weight loss in kilograms, percentage weight loss, and BMI change. There were no differences in age, current weight, current BMI, and time since surgery between surgical groups.

Pre- and post-surgical BMI categories are shown in Figure 3 by surgical type. Pre-surgery, all participants had a BMI over 30 and the majority had a BMI in the highest category, grade-III (81.4%). After surgery, 37.2% of participants no longer had a BMI in the obesity range, and only 11.6% of participants' BMIs remained within grade-III.

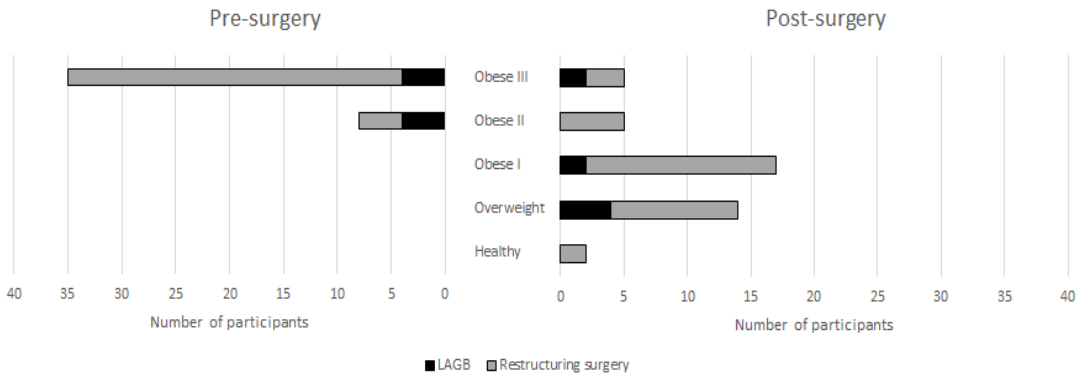

Figure 3. Number of participants with a BMI within each BMI category pre- and post-surgery according to surgical group.

The sample characteristics were compared to a recent UK cohort study based on bariatric surgery registries (Douglas et al., 2014) which indicated the study sample is representative in terms of age, gender and pre–surgical BMI. However, the study sample contained a higher proportion of people with RnY procedures and a smaller proportion of people with LAGB based on the bariatric registry data.

Thirty participants recorded at least one craving during the week of monitoring and 13 (30.2%) did not. Table 2 summarises demographic BMI and weight data according to craving groups. There were no significant differences between the craving group and non-craving group. Figure 4 shows the frequency of pre- and post-surgical BMI categories of participants according to craving group. After surgery, none of the people with a BMI in the healthy range reported a food craving, whilst all participants with a BMI in the obesity-III range did report a craving.

Table 7.

Demographic, weight and BMI history of participants (mean (S.E.) range); compared according to whether they did or did not experience a craving within the study week.

	Total sample	Craving group	Non-craving group	t(41)	*p*
n	43	30	13		
Age	52.14 (1.60) 30 - 72	51.10 (1.83) 30 - 70	54.54 (3.22) 32 - 72	0.99	0.33
Months since surgery	62.56 (4.11) 14 – 135	62.03 (5.43) 14 - 135	63.877 (5.59) 34 - 100	0.19	0.85
Current weight (kg)	91.71 (3.21) 67.70- 170.00	92.97 (4.20) 67.70-170.00	88.81 (4.41) 68.00 – 113.00	0.59	0.56
Current BMI (kg/m^2)	32.75 (1.01) 24.36 - 58.2	33.24 (1.35) 24.36 – 58.82	31.62 (1.29) 24.72 – 39.10	0.73	0.47
Pre-surgical weight (kg)	137.94 (3.70) 86.60 – 191.60	139.14 (4.45) 86.60 – 191.60	135.16 (6.86) 102.00 - 188.00	0.49	0.63
Pre-surgical BMI (kg/m^2)	49.52 (1.36) 34.22 – 76.29	49.92 (1.44) 34.22 – 66.30	48.61 (3.11) 36.24– 76.29	0.44	0.66
Weight loss (kg)	46.30 (2.71) 18.20 – 99.26	46.34 (3.41) 18.20 – 99.26	46.20 (4.48) 26.50 – 78.50	0.02	0.98
Weight loss (%)	33.24 (1.50) 11.27 – 55.14	33.02 (1.96) 11.27 – 55.14	33.77 (2.14) 23.25 – 50.32	0.23	0.82
BMI change	16.77 (1.06) 6.30 – 38.39	16.68 (1.21) 6.30 – 33.55	17.00 (2.21) 9.73 – 38.39	0.13	0.90

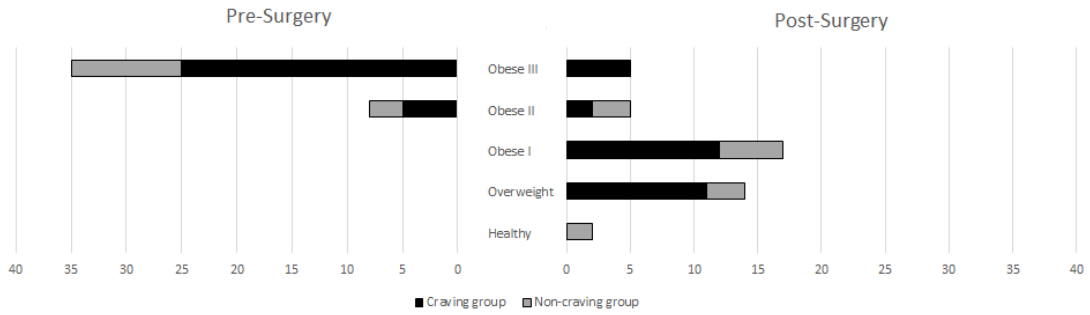

Figure 4. Number of participants with BMI values within each BMI category pre-and post-surgery according to whether or not they reported a craving.

Primary analyses

The primary research aim was to investigate the frequency and phenomenology of food craving in people who had received bariatric surgery, and examine differences between surgical types. Thirty participants reported at least one food craving (69.8%) and 13 did not report any food cravings (30.2%) during the study week. A total of 130 cravings were reported across the study week but two cravings were excluded from analysis as the craved item was a drink. The remaining 128 food cravings were analysed. Nineteen food cravings were reported by participants with LAGB and 109 reported by participants with a restructuring surgery.

Number of food cravings

Six participants with LAGB (75%) and 24 of the restructuring surgery group (68.6%) reported at least one food craving. The total number of food cravings reported by each participant is shown in Figure 5 ranging between zero and nineteen cravings over the week.

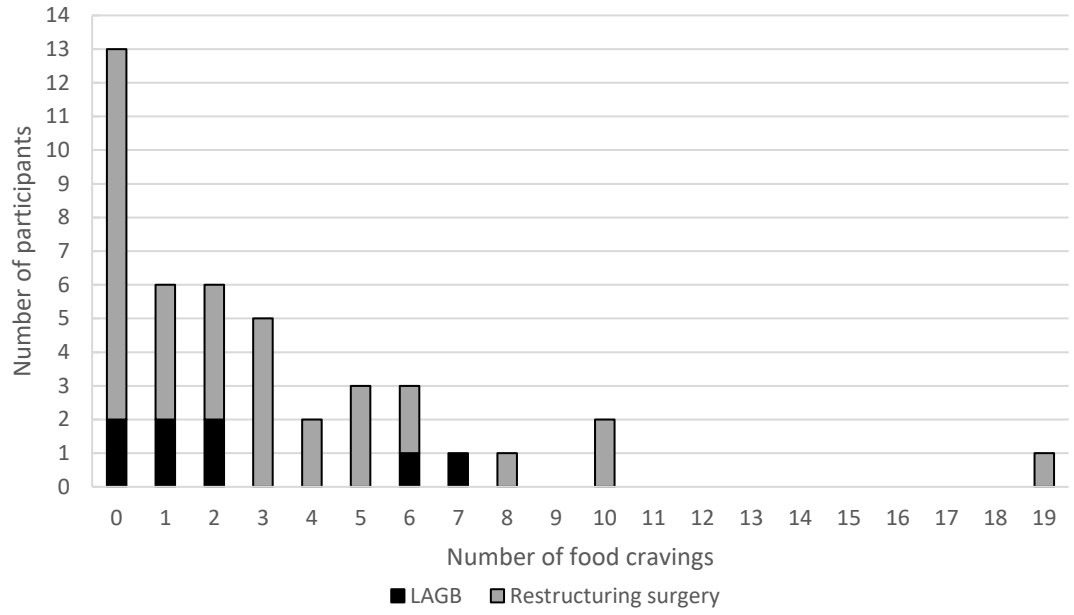

Figure 5. Number of food cravings reported over the study week by surgical type.

Across all participants (including those who did not report a food craving), the mean number of cravings experienced in a week was approximately three (Table 3). Participants in the restructuring surgery group reported slightly more cravings per week than the LAGB group but this was not significant ($t(41) = 0.502$, $p = 0.618$). After excluding the participant who experienced 19 cravings in a week, the mean number of cravings fell to 2.60

Table 8

Mean number of food cravings experienced during the study according to surgical groups (M (S.E., n))

	Total sample	LAGB group	Restructuring surgery group
All participants	2.98 (0.57, 43)	2.38 (0.94, 8)	3.11 (0.67, 35)
Cravers only	4.27 (0.69, 30)	3.17 (1.08, 6)	4.54 (0.82, 24)

After excluding the participants who did not report a craving, the mean number of food cravings experienced was 4.27, with participants in the restructuring surgery

group reporting slightly more food cravings compared with the LAGB group (note that a t-test was not conducted due to the small sample size; Table 3). After excluding the participant who experienced 19 cravings, the mean number of food cravings reported by the craving group over a week fell to 3.76.

Targets of food craving

The food cravings were divided into four categories based on previous classification by Hill, Weaver and Blundell (1991): *"chocolate", "sweet", "savoury"* and *"other".* Frequencies of targets of cravings are shown in Figure 6. Savoury foods were the most commonly craved category (57 cravings, 44.5%) and included predominantly carbohydrates, such as potato products and bread, and cheese. Forty-two sweet cravings were reported (32.8%), commonly for sugary carbohydrates such as biscuits, cakes and confectionary. Twenty-one were for chocolate (16.4%). Eight cravings were for other foods including sweet/savoury combinations e.g. "*chocolate, biscuits, and crisps*," textural cravings e.g. "*something crunchy*" and unspecific cravings such as "*any kind of protein*" (6.25%).

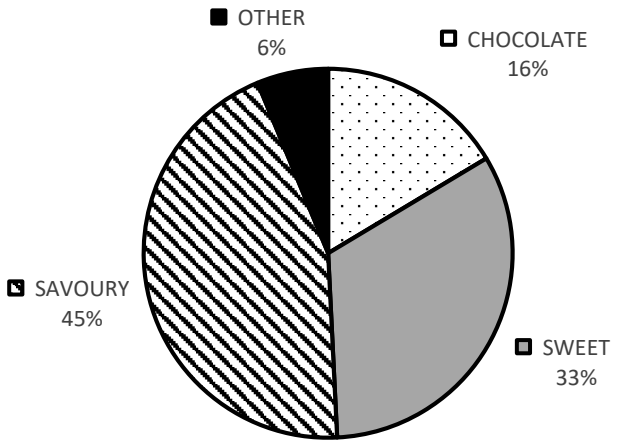

Figure 6. Proportion of food cravings according to food classification (Hill, Weaver & Blundell, 1991).

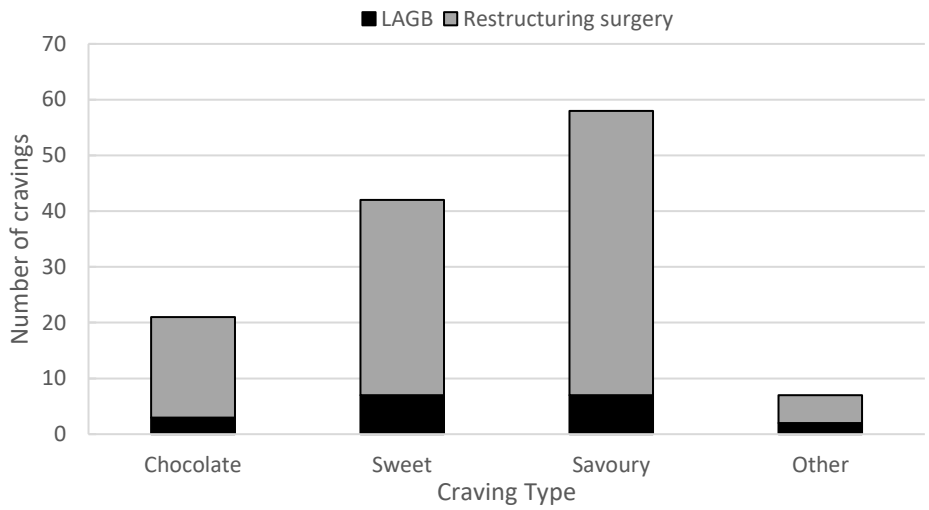

Figure 7. Frequency of food cravings within four classifications according to surgical type.

Figure 7 shows the number of cravings in each food group according to surgical type. There were no differences in the pattern of targets of cravings between surgical types.

Timing of food cravings

The frequency of food cravings across the day is shown in Figure 8. Food craving frequency peaked in the early afternoon in both surgical groups, although there was a smaller range of times reported from the LABG group (from 08:00 until 21:00 hours compared to between 02:00 and 23:00 hours in the restructuring surgery group). Six cravings were reported overnight between the hours of 00:00 and 06:00. Analysis of the free text commentary revealed that the night-time cravings were reported by three participants, two of whom experienced night-time cravings whilst working night shifts, and one participant reported being woken from sleep by food cravings.

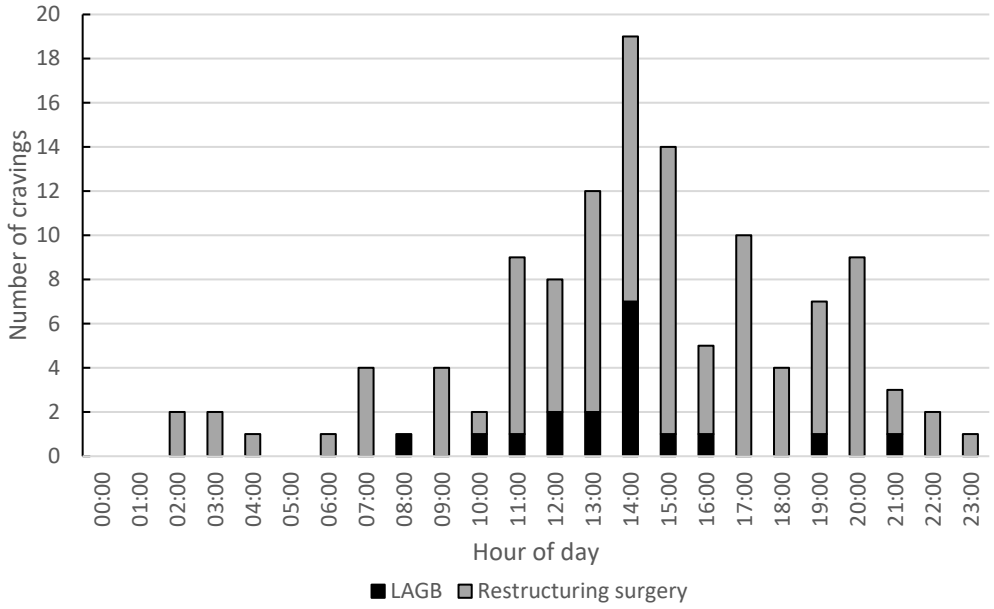

Figure 8. Frequency of food cravings reported within each hour block of 24-hour clock by surgical type.

Antecedents to food cravings

Participants were asked to identify events preceding their food craving from a list. Multiple antecedents could be selected. Only one antecedent was selected for 94 cravings (74.2%). For 17 cravings, two antecedent were identified (13.3%) and for three cravings, three antecedents were selected (2.3%). The most common antecedent was *"simply thinking about the food craved"* which preceded 71 cravings (55.5%). *"Seeing or smelling the craved food"* preceded 25 cravings (19.5%). *"Eating the craved food*" preceded 24 cravings (18.8%). *"Seeing or smelling another food*" preceded four cravings (3.12%). *"Thinking about another food"* preceded seven cravings (5.47%). *"Eating another food"* preceded seven cravings (5.47%). For 13 cravings, none of the above factors were reported as antecedents (10.2%) but examination of the free text responses revealed no other antecedents.

Participants rated how hungry they were at the time of the craving, and how much they had been restricting consumption of the craved food. The mean hunger

score across all participants was 4.10 (*S.E.* = 0.27); 3.37 (0.68) in the LAGB group and 4.27 (0.29) in the restructuring surgery group. The mean restriction score was 4.43 (0.31); 3.16 (0.69) in the LAGB group and 4.65 (0.34) in the restructuring surgery group. There were no significant differences in hunger ($t(126) = 1.14$, $p = 0.26$) or restriction scores ($t(125) = 1.73$, $p = 0.09$) between surgical groups.

Experiential and sensory components of food cravings

Participants rated the intensity of four sensory domains of food cravings (vividness of imagery, taste, smell and physical sensation), strength of food craving, and difficulty to resist. The mean rating of the four sensory domains was calculated to provide a total sensory score. All sensory and experiential components received moderate ratings (Table 4).

Table 9

Ratings of experiential components of food cravings according to surgical group (mean (S.E., n))

	Total sample	LAGB group	Restructuring Surgery group
Strength of craving	4.27 (0.26, 128)	**3.05 (0.64, 19)**	**4.48 (0.28, 109)***
Difficulty to resist	4.97 (0.31, 128)	**3.16 (0.75, 19)**	**5.28 (0.33, 109)***
How vividly could you picture the food in your mind?	4.47 (0.31, 127)	4.05 (0.81, *19*)	4.54 (0.33, *108*)
How vividly could you imagine the taste?	4.03 (0.31, 127)	3.42 (0.75, *19*)	4.14 (0.34, *108*)
How vividly could you imagine the smell?	4.70 (0.35, 127)	3.11 (0.63, *19*)	4.99 (0.38, *108*)
How vividly could you imagine the feeling of the food?	4.80 (0.35, 127)	4.53 (0.79, *19*)	4.85 (0.38, *108*)
Total sensory score	4.47 (0.26, 127)	3.78 (0.62, *19*)	4.59 (0.28, *108*)

* **difference between surgical groups, p <0.05**

Mann-Whitney U tests revealed no significant differences between groups in the vividness of imagery ($U(125) = 1096$, $p = 0.632$), taste ($U(125) = 1112$, $p = 0.555$), smell ($U(125) = 1251$, $p= 0.123$) or feeling, ($U(125) = 1015$, $p = 0.94$) or the combined sensory score ($U(125) = 1206$, $p = 0.252$). However, the participants who had received

restructuring surgery reported significantly stronger cravings (U(126) = 1367, p = 0.025) and rated cravings as significantly more difficult to resist (U(126) = 1405, p = 0.013) than participants who had received LAGB.

Responses to food cravings

Table 5 shows that 74.2% of cravings experienced resulted in an eating episode, and the majority of fulfilled cravings were fulfilled by eating the craved food item (89.5%). Conversely, a quarter of all cravings were resisted (25.8%). In the LABG group, just under half of all cravings were resisted (47.4%), but in the restructuring surgery group, less than one quarter of cravings were resisted (22.0%). In both groups, almost all fulfilled cravings were fulfilled by the target food (90% LABG, 89.4% restructuring surgery group).

Table 10

Number of cravings reported, resisted or fulfilled, by surgical group

	All cravings	LAGB group	Restructuring Surgery group
n cravings	128	19	109
Resisted	33	9	24
Fulfilled	95	10	85
Fulfilled by craved food	85	9	76

Participants who fulfilled a craving estimated the amount of time in minutes that they resisted. The mean amount of time a food craving was resisted was 33.5 minutes (range 0 – 360 minutes; *S.E.*= 5.12). Over half of cravings (57.9%) were fulfilled within 15 minutes after the craving started, and 87.4% within 60 minutes.

(Figure 9). The mean time in minutes a craving was resisted in the LAGB group (45.6 minutes, 11.4 S.E.), was slightly longer than in the restructuring surgery group (32.1 minutes, 5.57) but this difference was not statistically significant ($t(93) = 0.81$, $p = 0.42$).

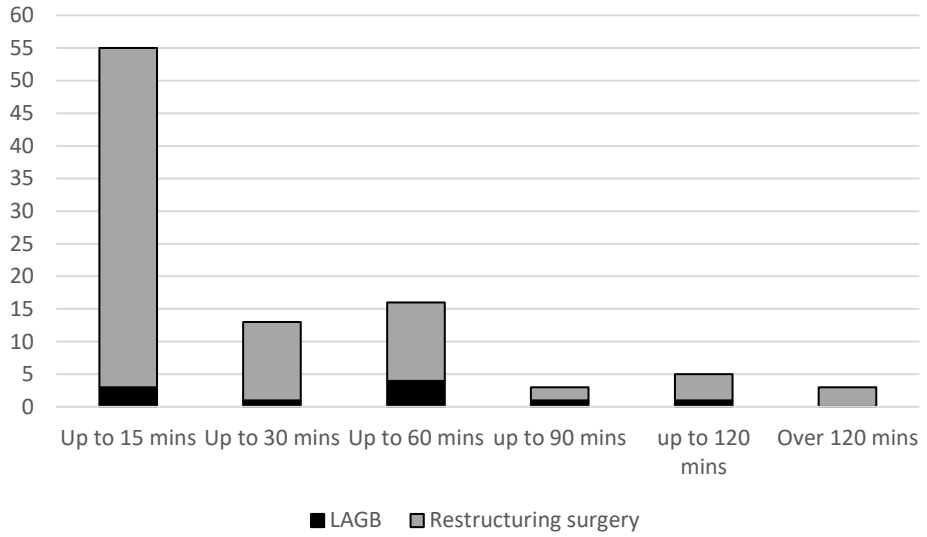

Figure 9. Time in minutes cravings were resisted according to surgical group.

For cravings that led to an eating episode, participants were asked to rate the pleasantness of the food they ate. The mean pleasantness rating of all cravings was 5.48 (0.33), 4.40 (1.12) in the LABG group and 5.61(0.34) in the restructuring surgery group. The difference in pleasantness scores between surgical groups was not significant ($t(93) = 1.14$, $p = 0.26$).

Context of food cravings

End of day questionnaire data were collected for 297 days. The LAGB group contributed data for 54 days and the restructuring surgery group contributed data for 243 days. At least one food craving was reported on 96 of all days (32.3%).

Time elapsed after previous meal

For each individual food craving, the corresponding meal pattern questionnaire was used to calculate the number of one-hour blocks that had elapsed since the eating

episode prior to the craving. Thirteen food cravings were excluded due to incomplete time data. One-hundred and fifteen cravings were analysed and shown in Figure 10. Over half (53.9%) of all reported cravings occurred within two hours of a meal. Both surgical groups showed a similar pattern, with fewer food cravings reported the more time elapsed since an eating episode. Where the time elapsed was over 10 hours, the previous eating episode occurred the previous evening with the food craving occurring in the morning before the first meal of the day.

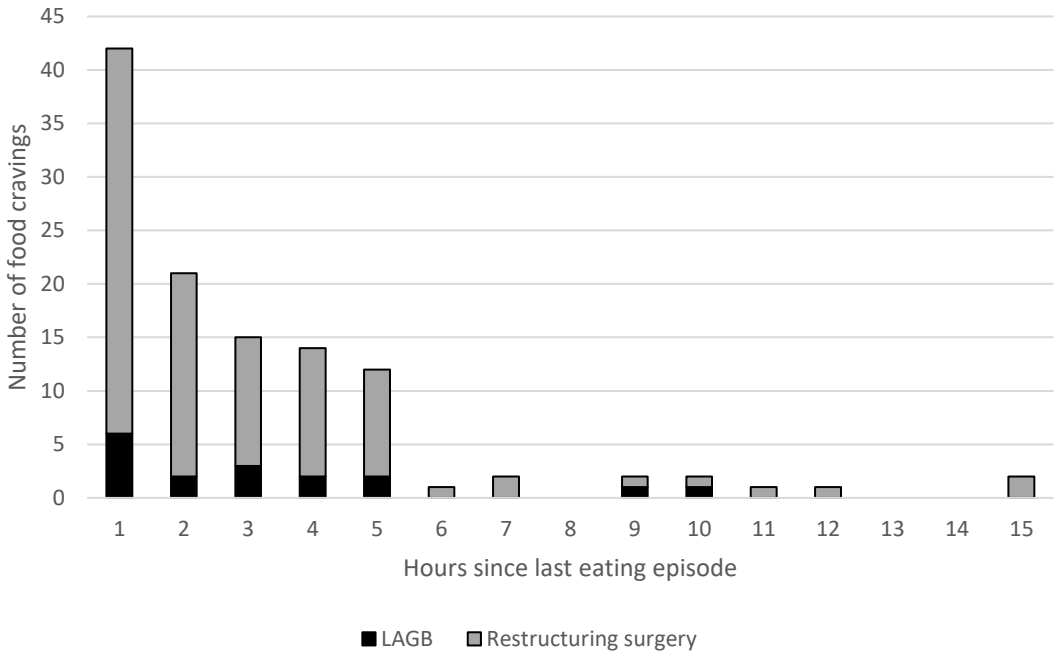

Figure 10. Frequency of food cravings which occured in hours after previous eating episode.

End of day ratings

Participants were asked to rate how they felt each day on eight factors shown in Table 6. Only responses from participants who reported at least one craving were included. Table 6 shows that overall, participants experienced higher anxiety, more tension, more irritability and more boredom on craving days. They also experienced stronger hunger, stronger desire to eat and lower control over eating on craving days. This pattern was consistent across the two surgical groups.

Mixed-model analysis revealed cravings days were characterised by lower control of eating (estimate = -0.95, S.E. = 0.38, $t(200) = 2.53$, $p = 0.012$), greater levels of hunger (estimate = 0.82, S.E. = 0.30, $t(200) = 2.71$, p = 0.007) and higher irritability (estimate = 0.64, S.E. = 0.32, $t(200) = 1.99$, $p = 0.048$). There was no significant effect of surgical type.

Table 6

Mean (S.E) ratings of all days, craving days and non-craving days according to surgical group.

	Total sample			LAGB group			Restructuring surgery group		
	All days	Craving days	Non-craving days	All days	Craving days	Non-craving days	All days	Craving days	Non-craving days
n	*206*	*96*	*110*	*40*	*18*	*22*	*166*	*78*	*88*
Anxiety	2.63 (0.20)	3.20 (0.30)	2.13 (0.26)	2.55 (0.39)	3.61 (0.65)	1.68 (0.39)	2.64 (0.23)	3.10 (0.34)	2.24 (0.31)
Control of eating	6.25 (0.19)	**5.76* (0.28)**	**6.68* (0.27)**	6.48 (0.42)	5.56 (0.60)	7.23 (0.55)	6.20 (0.22)	5.81 (0.32)	6.55 (0.30)
Contentment	6.32 (0.20)	6.05 (0.29)	6.55 (0.28)	7.08 (0.31)	6.67 (0.40)	7.41 (0.45)	6.13 (0.24)	5.91 (0.35)	6.33 (0.33)
Hunger	4.23 (0.17)	**4.73* (0.25)**	**3.79* (0.23)**	4.13 (0.44)	5.56 (0.65)	2.95 (0.46)	4.25 (0.19)	4.54 (0.26)	4.00 (0.26)
Tension	3.38 (0.20)	3.79 (0.29)	3.03 (0.28)	3.40 (0.43)	4.44 (0.62)	2.55 (0.53)	3.38 (0.23)	3.64 (0.33)	3.15 (0.33)
Irritability	2.84 (0.18)	**3.51* (0.28)**	**2.25* (0.23)**	3.63 (0.46)	4.44 (0.67)	2.95 (0.59)	2.65 (0.20)	3.29 (0.31)	2.08 (0.24)
Desire to eat	4.35 (0.17)	4.78 (0.24)	3.97 (0.24)	3.58 (0.41)	4.83 (0.64)	2.55 (0.45)	4.54 (0.19)	4.77 (0.26)	4.33 (0.27)
Boredom	1.82 (0.15)	2.26 (0.25)	1.43 (0.19)	2.10 (0.42)	3.44 (0.64)	1.00 (0.44)	1.75 (0.16)	1.99 (0.26)	1.54 (0.20)

***significant difference between craving and non-craving days**

Predictors of craving intensity

Intensity was calculated by summing strength and difficult to resist scores. Creation of a decision tree (Figure 11) showed that the intensity of the craving was influenced by imagined taste. The taste component could be divided into two groups – a low taste (node 1) and a high taste group (node 2). The low taste group included

90 cravings with a imagined taste rating of 6.0 or lower, which had a mean craving intensity score of 7.3. The high taste group contained 38 cravings with an imagined taste rating over 6.0, which had a mean craving intensity score of 13.7. Within the low taste group, craving intensity was related to the two surgical groups. Cravings from people with LAGB (node 3) were rated lower in intensity (3.60) compared with the restructuring surgery group (node 4, 8.08). In the high taste group, smell was the best classifier. The group of cravings with ratings of imagined smell greater than 9.0 had a lower mean intensity score (11.0, node 6) when compared to the group of cravings with a less vivid imagined smell (less or equal to 9.0) (15.5, node 5).

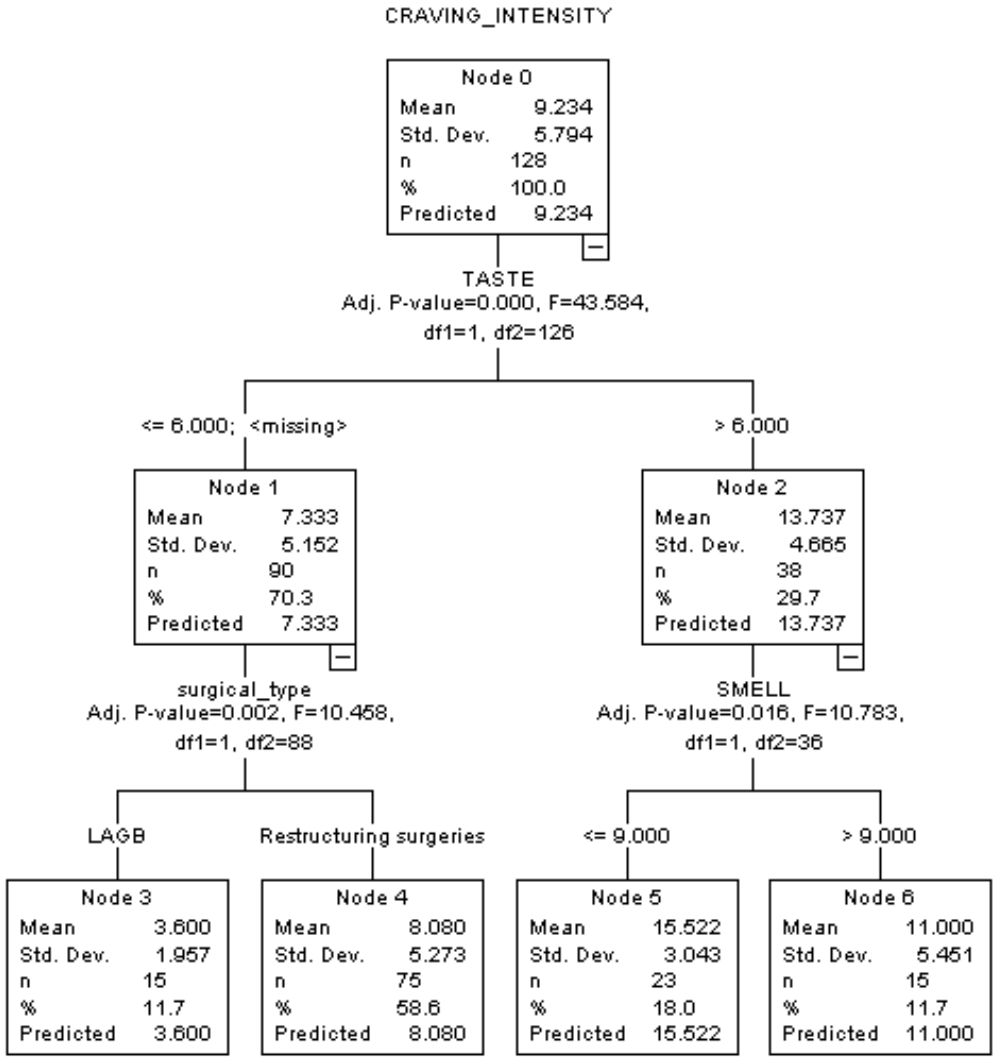

Figure 11. Decision tree of factors that influence craving intensity.

Predictors of eating in response to craving

Tree classification indicated that the best model of eating in response to craving was based on two antecedents: eating the food and thinking about the food. Where the participant was eating the target food before the craving occurred, the craving was fulfilled in all cases (node 2). If the person was not eating the food, eating occurred 68.3% of the time (node 1), but this increased to 77.4% of the time if the participant

was thinking about the craved food (node 3), compared to only 54.8% of the time if they did not think about the food (node 4; Figure 12).

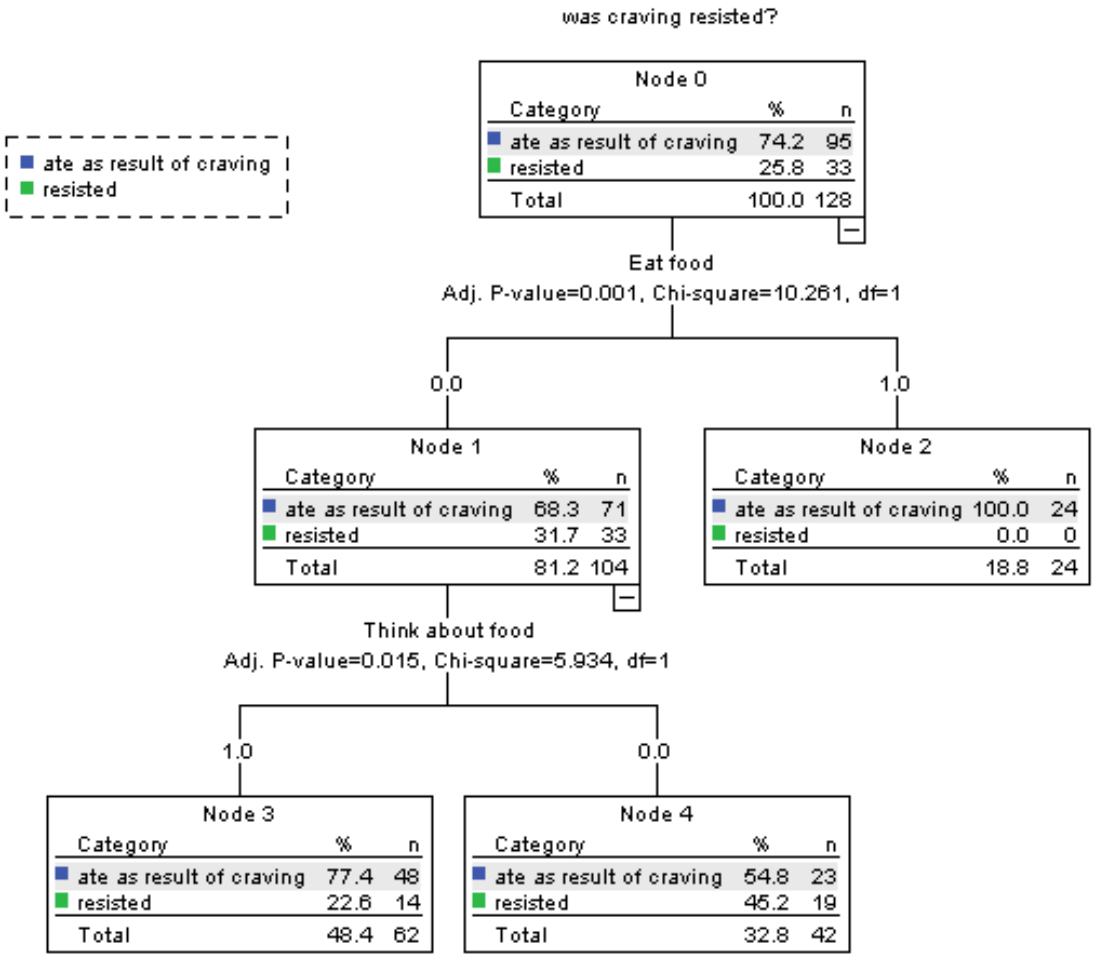

Figure 12. Decision tree showing factors that influenced craving resistance.

Secondary analyses

The secondary research aims concerned the relationship between food cravings and weight change, eating patterns, disordered eating behaviour and mental imagery. Participants were compared according to surgical type, and according to whether or not they reported a craving.

Eating pattern, mood and mental imagery

Participants' scores on the background information questionnaires concerning eating behaviours, mood and strength of mental imagery are given in Table 9 by their surgical group. Comparison of the surgical groups revealed one significant difference. Participants in the restructuring group reported higher anxiety scores as measured by the DASS.

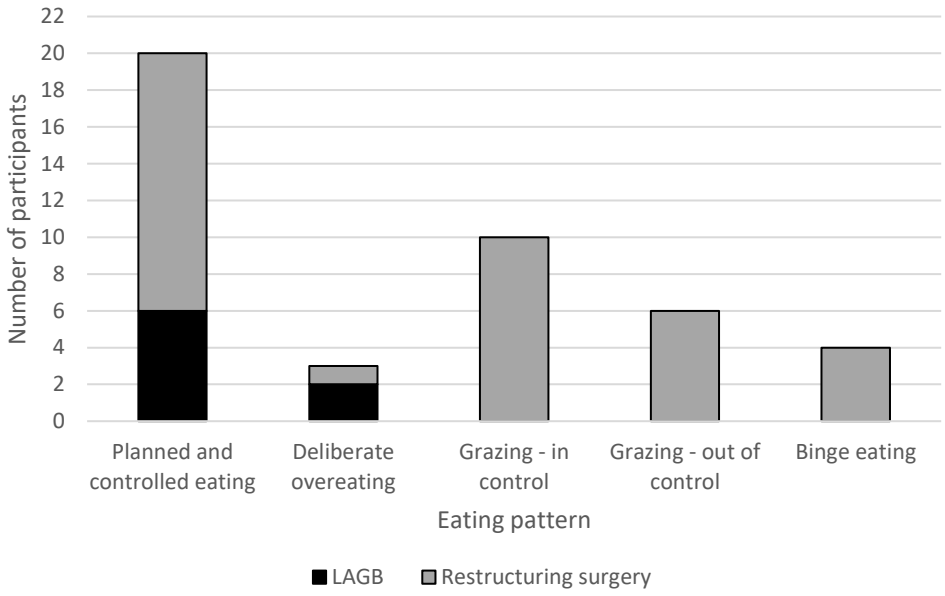

Figure 13. Self-defined eating pattern according to surgical type.

Figure 13 shows participants' self-described eating patterns. Over two-thirds of participants categorized their eating pattern as either "*planned or controlled*", or "*grazing but in control"* (69.8%). Of the remaining participants, 7.0% said they "*deliberately overate*", 14.0% said they were *"grazing out of control"* and 9.3% described their eating pattern as *"binge eating".* All participants with a LAGB described themselves as either *"planned or controlled eating"* (75%) or *"deliberate over eating"* (25%).

Table 7.

Comparisons of mean (S.E.) scores on eating, mood and mental imagery questionnaires according to surgical group

	Total sample	LAGB group	Restructuring surgery group	Statistical significance	
n	43	8	35		
				U(41)	*p*
DASS Anxiety	5.44 (1.09)	1.25 (0.53)	6.40 (1.29)	**218.00**	**0.01**
DASS Depression	7.58 (1.51)	3.00 (1.13)	8.63 (1.79)	173.50	0.30
EDE-Q Restriction	7.16 (0.91)	7.88 (2.40)	7.00 (0.99)	128.50	0.73
EDE-Q Overvaluation	6.26 (0.76)	5.75 (1.75)	6.37 (0.85)	158.00	0.59
EDE-Q Dissatisfaction	6.44 (0.76)	5.13 (1.92)	6.74 (0.83)	166.50	0.42
				t(41)	*p*
SUIS	36.47 (1.72)	35.50 (3.16)	36.69 (2.00)	0.27	0.73
TFEQ Emotional eating	13.14 (0.79)	15.48 (1.76)	12.63 (0.87)	1.37	0.18
Grazing	10.84 (1.07)	6.88 (1.49)	11.74 (1.22)	1.82	0.08

Table 7 shows participants' scores on background questionnaires concerning eating behaviour, mood and mental imagery according to surgery type. The LABG group reported significantly lower anxiety than the restructuring group.

Table 8 shows participants' scores on background questionnaires concerning eating behaviour, mood and mental imagery according to craving group. Participants who experienced a food craving reported significantly greater emotional eating as measured by TFEQ, and significantly greater eating restriction as measured by the EDE-Q.

Table 8

Comparisons of mean (S.E.) scores on eating, mood and mental imagery questionnaires according to whether the participant reported a food craving

	Total sample	Craving group	Non-craving group	Statistical significance	
N	43	30	13		
				U(41)	*p*
DASS Anxiety	5.44 (1.09)	5.93 (1.26)	4.31 (2.22)	244.00	0.20
DASS Depression	7.58 (1.51)	8.53 (1.89)	5.38 (2.45)	259.50	0.09
EDE-Q Restriction	7.16 (0.91)	8.77 (1.04)	3.46 (1.42)	**298.50**	**0.01**
EDE-Q Overvaluation	6.26 (0.76)	7.13 (0.89)	4.23 (1.33)	261.00	0.08
EDE-Q Dissatisfaction	6.44 (0.76)	7.33 (0.91)	4.34 (1.25)	259.50	0.09
				T(41)	*p*
SUIS	36.47 (1.72)	38.27 (1.89)	32.31 (3.50)	1.62	0.11
TFEQ Emotional eating	13.14 (0.79)	14.27 (0.87)	10.54 (1.47)	**2.27**	**0.03**
Grazing	10.84 (1.07)	11.37 (1.20)	9.62 (2.24)	0.75	0.46

Figure 14 shows participants' self-defined eating patterns according to whether or not they experienced a craving. Approximately equal proportions of each group defined their eating as *"grazing but out of control"* (15.4% non-craving group, 13.3% craving group) and "*binge eating"* (7.70% non-craving group, 10% craving group). However, more of the non-craving group said they were "*deliberately overeating*" (15.4% non-craving group, 3.33% craving group) or *"planned and controlled"* (53% non-craving group, 43% craving group). More of the craving group described their eating pattern as *"grazing but in control"* (30% craving group, 7.69% non-craving group). Tests for differences in proportions (z score) were not conducted due to small sample size.

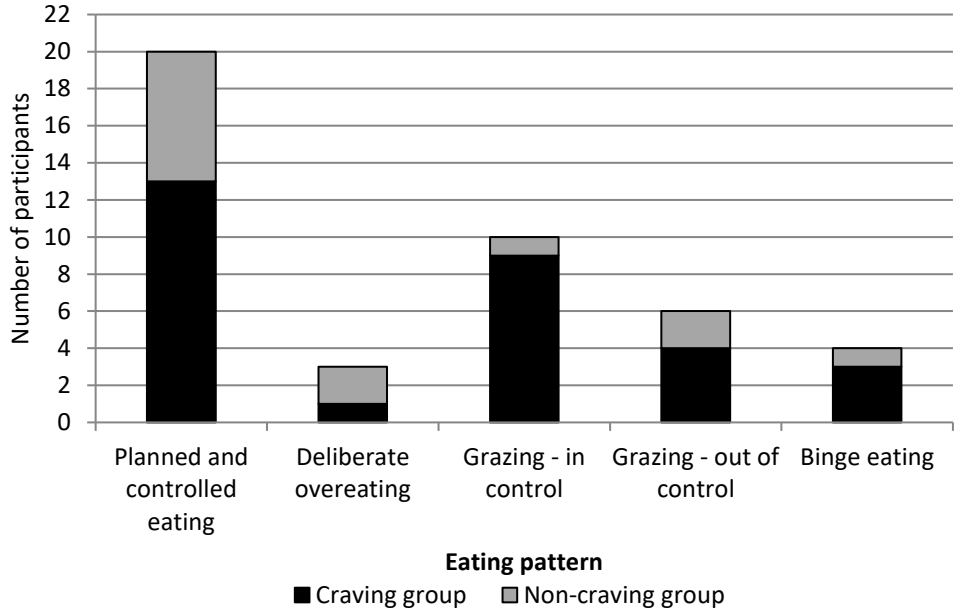

Figure 14. Self-defined eating pattern according to whether or not participant reported a craving.

Model of craving intensity

Mixed-model analysis revealed craving intensity was best related to two variables: eating the food craved and seeing/smelling the food craved. Previously eating the food craved increased the rating of craving intensity by 3.11 points, and seeing or smelling the food craved increased the intensity by 2.92 points. Previously thinking about the food craved fell below the cut-off *t*-value of 2.0 but has been included in the model as the high t-value suggests it could be an important factor. The variance in the data attributed to the participant was 16.9%, and there was a residual variance of 12.8%. The model is shown in Table 9. Correlations between fixed effects are contained in Appendix C.

Table 9

Model of fixed effects which predict craving intensity (120 df).

Fixed effects	Estimate	Standard Error	*t*	*p*
(Intercept)	7.59	1.13	6.70	
Seeing or smelling the food craved	2.92	1.17	**2.50**	**0.01**
Eating the food craved	3.11	1.35	**2.31**	**0.02**
Thinking about the food craved	1.54	0.85	1.82	0.07

Model of craving resistibility

Mixed-model analysis demonstrated that resisting the food craving was best predicted by one variable: seeing or smelling the food. Seeing or smelling the food craved made it around 4 times more likely the participant would resist the food craving. At the 10% significance level, participants were slightly less likely to a resist craving as time since surgery increased, and as overvaluation scored increased. Surgical type was not a significant predictor (Table 10). Correlations between fixed effects are shown in Appendix C.

Table 10

Model of fixed effects which predict craving resistance (120 df)

Fixed effects	Estimate	Standard Error	*p*	Odds ratio
(Intercept)	0.20	0.76	0.78	1.22
Seeing or smelling the food craved	1.43	0.60	**0.02**	4.19
Time since surgery (months)	-0.02	0.01	0.08	0.98
EDE-Q overvaluation	-0.10	0.05	0.06	0.91

Supplementary analyses

In the background information questionnaire, participants were asked if they had experienced any food cravings in the past week and reported their most frequently craved food. Frequencies are shown in Table 11. Thirty-five participants (81.4%) reported a craving either retrospectively in the background questionnaire or contemporaneously during the study week. Thirty-one participants (72.1%) showed consistency in responses between the retrospective and contemporaneous reporting (i.e. a craving in the previous seven days, and a craving during the study week, or no craving in both periods). Twelve participants (27.9%) reported a craving in one week but not the other.

Table 11

Frequency table showing the number of participants who reported a food craving retrospectively or contemporaneously

N		Retrospective food craving (background information)	
		Craving	No craving
Contemporaneous food craving (Food craving record)	Craving	23	7
	No craving	5	8

Participants were asked to retrospectively rate phenomenological characteristics of the recalled food cravings in terms of strength, resistibility and the visual imagery. Participants also rated how easy it was to visualise the food in the present moment. The mean scores are shown in Table 12. Paired-sample t-tests revealed that participants' retrospective ratings were significantly higher than contemporaneous ratings for the strength of food craving ($t(27) = 8.52$, $p < 0.001$), the difficulty resisting the craving ($t(27) = 5.97$, $p < 0.001$) and the clarity of the mental image of the food ($t(27) = 2.59$, $p = 0.02$). Participants reported it was easy to visualise the food at recall.

Table 12

Mean (S.E., n) ratings of retrospective food cravings (background information) compared to scores from contemporaneous reporting (food craving record)

Mean (S.E., n)	Retrospective food craving	Contemporaneous food craving
Strength	**7.54 (0.38, 28)***	**4.27 (0.26, 128)***
Difficulty to resist	**7.71 (0.34, 28)***	**4.97 (0.31, 128)***
Clarity of image of food	**7.14 (0.58, 28)***	**4.47 (0.31, 127)***
Clarity of image of eating the food	6.68 (0.60, 28)	
Ease of visualising the food at recall	8.34 (0.44, 28)	

*** Significant differences between retrospective and contemporaneous craving**

Of the 28 retrospective food cravings, half of food cravings were for savoury foods (15, 53.6%), followed by chocolate cravings (6, 21.4%) and sweet cravings (17.9%). Food cravings for other foods or combinations of food types accounted for just 7.14% of the responses. This was comparable to contemporaneous food cravings.

DISCUSSION

To date, there has been limited study of the experience of food craving in people who have received bariatric surgery. These mainly involve retrospective, self-report questionnaires that simply record the frequency and type of cravings experienced in the period immediatly post-surgery without questioning the phenomenology in detail. In addition, previous research is concentrated on the first few years post-surgery. The present study aimed to address these issues by using a CIA methodology, with the option to use internet-enabled devices for recording, to collect a rich set of descriptive, ecologically-valid and contemporaneous data about the lived experience of food craving from people who received bariatric surgery up to ten years previously. The primary research aims were to describe the phenomenology of food cravings within this group and investigate any difference in experience based on surgical type. Secondly, this study aimed to relate craving experiences to weight change, eating patterns and disordered eating after bariatric surgery of different types, and finally, to investigate the relationship between mental imagery and craving experience.

The phenomenology of food cravings in people with bariatric surgery

This study provides an understanding of craving experiences in terms of their frequency, the context in which they occur, experiential and sensory qualities of the food craving, and the response to the craving. The results are outlined below in the context of the previous literature.

Frequency of food cravings

The results showed 81% of participants reported at least one food craving (either retrospectively in the week preceding the study, or during the study week itself), averaging between two and four cravings a week. These are much higher figures than reported in the previous literature, for example Harbottle (2011) reported only 47% of post-surgical patients reported food cravings in the five years after surgery, and Leahey et al (2011) reported two to three cravings per month. This discrepancy may be due to methodological differences as both authors used one-off retrospective questionnaires to measure craving. Furthermore, Harbottle (2011) asked participants *"do you experience strong food cravings?"* which may have led to negative responses if participants did not regularly experience cravings, or felt their cravings were not *"strong"*. Conversely the results of this study are consistent with the previous CIA study concentrating on experiences in the first year post-surgery (Guthrie et al., 2014), and it does not appear that craving frequency diminishes with additional time since surgery. Certainly, food cravings are commonly and frequently experienced by people living with bariatric surgery long-term.

Context of food cravings

Cravings were most often experienced after simply thinking about the food craved, which is consistent previous research within a post-surgical group (Guthrie et al., 2014) and people with a healthy BMI (Hill et al., 1994). This suggests that internal cues alone are sufficient to stimulate food cravings. However, external cues also play a role as participants commonly identified the sight, smell and eating of food preceding food cravings.

Reporting of food cravings peaked in the early afternoon and half of cravings occurred within two hours of a meal. The likelihood of craving onset decreased as time increased following an eating episode but some participants continued to experience cravings for many hours after a meal. This was consistent with results reported by Guthrie et al (2014), and contrasts with the experience of people who are dieting and people with healthy BMIs (who tend to experience cravings later in the day). Ratings of hunger and food restriction given at the time of the craving were moderate, confirming that hunger and restriction are not sufficient to explain craving experiences, again in line with previous literature (Hill, 2007; Boswell & Kober, 2016). On the other hand, craving days were characterised by greater levels of hunger, lower eating control and higher irritability than days in which a craving did not occur. It is important to note that these ratings were made at the end of each day so cause and effect is impossible to determine. Whilst it may be that lower mood, lower eating control and greater hunger precipitated the experience of food cravings, it is also plausible that participants (having experienced a food craving and in the majority of cases, eaten as a result) rated themselves as hungrier, less in control and more irritable in response to their craving experience. Thus similarly to previous research, the results can only point to an association between mood, eating control and food craving without determining causality (Hill et al., 1991; Gendall et al., 1998).

Experiential and sensory qualities of food cravings

The most frequent targets of food cravings by people after bariatric surgery were savoury foods, which accounted for nearly half of all cravings. This was followed by cravings for sweet foods and a smaller proportion of cravings for chocolate. The remaining cravings covered cravings described in terms of texture or nutritional content and combinations of sweet and savoury cravings. This is pattern is consistent

with previous reports in post-surgical groups (Guthrie et al., 2014; and Leahey et al., 2011). Interestingly, the pattern of foods craved post-surgery is different than those experienced by the general population. In studies of people with healthy or overweight BMIs, the majority of food cravings are for chocolate, followed by sweet foods. Savoury foods are the least frequently craved (Weingarten & Elston, 1991; Hill et al., 1994; Gendall et al., 1997). For people who have bariatric surgery, eating foods heavy in sucrose or fructose can induce "dumping syndrome" (typically nausea, vomiting, diarrhoea, sweating, and severe stomach cramps). Therefore, experiences of dumping syndrome can create a learnt cue-response in which sweet foods and chocolate are associated with the unpleasant effects of dumping syndrome and now considered unpleasant and undesired stimuli – a form of conditioning known as "taste aversion" (Bernstein, 1999). Additionally, bariatric patients report intolerances for savoury carbohydrates such as bread, rice and pasta in the two years following bariatric surgery (Harbottle, 2011) and consequently these foods are likely to be restricted within the diet. This fits with research that suggests food cravings are more likely to occur for foods which are restricted (Massey & Hill, 2012). One possibility is that participant's experienced food cravings predominantly for chocolate before their surgery, and the procedure itself was responsible for the change in craving preference towards savoury foods. However, as no information was collected on pre-surgical cravings, it is possible that the sample have historically preferred savoury foods, especially as individuals with obesity who have not received bariatric surgery also more frequently crave savoury foods (Guthrie et al, 2014). This points to the possibility that savoury food preference may occur during the process of weight gain, or may be a result of efforts to control weight once it has been gained, and consequently the likelihood of receiving bariatric surgery, rather than bariatric surgery precipitating savoury cravings.

Sensory mental imagery including imagined picture, smell, taste and feeling were identified as part of the experience of food cravings, and all four sensory components were rated equally by participant with no one part of the image dominating. Mixed-model analysis showed that the best predictors of craving intensity were seeing, smelling and eating the food craved. This is supportive of results published by Tiggemann and Kemps (2005) in which visual imagery, followed by taste and smell, were most frequently described components in the experience of food craving; and the vividness of these sensory domains was correlated with craving intensity.

Responses to food cravings

Three-quarters of food cravings resulted in an eating episode, of which the majority resulted in eating the craved food. Out of the cravings which were fulfilled, over half resulted in eating within 15 minutes, and almost all eating occurred within an hour. This is an important finding as if cravings result in eating, then this consumption of additional calories may inhibit weight loss or its maintenance, and lead to weight gain. Furthermore, previous research has shown that eating as a result of food cravings is associated with negative mood states, and negative mood states are associated with additional craving (Macdiarmid & Hetherington., 1995), thus creating a maladaptive eating cycle driven by low mood and food craving. Likewise, a learnt cue-response association between craving and eating pleasure may also create a reinforcement loop. However, pleasure ratings for food consumed post-craving were only moderate, and there was no measure of the pleasantness associated with the act of eating or the way in which pleasure dissipated once eating began.

Where a food craving immediately followed eating the craved food the craving was fulfilled in all cases. This is an unsurprising result considering the multisensory experience and the likely accessibility of the craved food. For example, one participant described eating one biscuit from the tin, experiencing a craving for more and so returned to the biscuit tin for another. Interestingly craving intensity was not included in decision trees or mixed-models as a key predictor of resistibility, which suggests that other characteristics of either the food craving, the individual, or the context, drove the decision to eat or not. The results highlighted some possibilities. Firstly, when the food was not being eaten, thinking about the food had greatest influence on resistibility, supporting to the theory that cognition is a predominant component of food craving as per the EI model (May et al., 2014). Secondly, mixed-model analysis showed that the best predictor of resistance of food craving was seeing or smelling the craved food. This is a counter-intuitive result and a possible explanation for this result is outlined later (see section "Relationship to EI model of food craving"). However, it must be acknowledged that participants identified seeing or smelling the food as an antecedent in less than a fifth of the reported food cravings. Furthermore, the statistical method can produce false positives (see strengths and weaknesses section). As such, this result needs to be interpreted with caution and investigated with future study.

The influence of surgical type on food craving

The four main types of bariatric surgery all aim to induce weight loss and improve eating control, but differ in their methods of achieving this. Surgeries have different effects on physical capacity, absorption of nutrients, the production of hormones, gut peptides, satiety, changes in taste and food aversion, changes in gut

peptides, and neural and hormonal mediators (e.g. O'Brien, 2010; Tam et al, 2011), with more distinct differences noted between LAGB and restructuring surgeries. For example, LAGB is associated with lower food tolerance and increased gastrointestinal symptoms than restructuring surgeries (Overs et al 2012). Thus, this study investigated the possibility that food cravings might be experienced differently between surgical types.

There was some evidence that food cravings were experienced differently by people with LAGB compared to other surgeries. Participants in the restructuring group rated their cravings as stronger and more difficult to resist, and were more likely to eat in response to their cravings than people with LAGB. Cravings also occurred over a broader portion of the 24-hour day than in the LAGB group, although this may be due to the smaller sample size in the LAGB group. Whilst previous research has suggested intensity of craving is associated with stronger mental imagery (Tiggemann & Kemps, 2005), there was no difference in the scores relating to sensory imagery between surgical groups. More nuanced investigation of the data using decision trees suggested that surgical type only influenced intensity when the taste imagery was low. On the other hand, mixed-model analyses did not reveal a relationship between surgical type and either craving intensity or craving resistibility. Of course, the very small sample of people with LAGB included in this study makes the lack of conclusive results unsurprising, and the differences that have emerged need to be considered with caution.

Previous research suggests that LAGB is associated with a greater prevalence of gastrointestinal and eating complications compared to other methods (Overs et al., 2012). Subsequently this tentative picture that people with LAGB experience less intense cravings which are easier to resist is inconsistent. However, people who find

LAGB unsuitable frequently opt for band removal, and in many cases, undergo a restructuring surgery to achieve weight loss (Himpens et al, 2011). This could mean that the sample of people with LAGB included in this study represents only those for whom gastric banding worked (who tolerated the band and achieved the desired weight loss with lower negative symptomology). This was especially likely as a ten-year post-surgery sample was recruited where there had been ample opportunity for removal and revision. Moreover, the LAGB group were lower in weight with a lower BMI pre-surgically, reported less anxiety, and were more likely to report planned and controlled eating patterns. This is consistent with current practice which advocates the use of LAGB in patients with BMI values at the lower end of the obesity spectrum. As patients are not randomised to surgery, this raises the issue that the LAGB group represent a cohort of patients quite distinct from the restructuring surgery group. It is possible that the LAGB cohort were less anxious, more controlled and less maladaptive in their eating pre-surgery which resulted in lower BMI values compared to those offered restructuring surgery. Therefore, any differences in the experience of food cravings could be due to these cohort characteristics rather than the effect of the surgical procedure.

The differences between those who crave food and those who do not

Not all participants in this study reported a food craving. This raises an interesting question: what factors distinguished those who craved food from those who did not? Whilst there was no difference in current weight, weight loss or BMI between those who reported a craving and those who did not, all participants whose BMI was over 40 did report at least one craving whereas the participants within the healthy BMI range reported no cravings. This lends some support to the idea that food

cravings may be a predictor of obesity (Schuldt et al., 1993). Previous research suggests food cravings are associated with maladaptive eating patterns (e.g. Gendall et al., 1998) and correspondingly, participants who experienced a craving reported greater emotional eating, greater eating restriction, and grazing eating patterns than those who did not. However, cravings were experienced by people across all eating patterns, including those who identified themselves as planned and controlled eaters. The more important question clinically is whether or not people ate in response to their craving, and whether participants who could consistently resist cravings differed from the group that struggled to resist cravings. Due to the small size of the groups, this further analysis was not conducted.

Relationship to the EI model of food craving

Until recently, the food craving literature was dominated by two major theories – firstly, that food cravings were induced by nutrient deficiency and eating restriction, and secondly, that food cravings represented a learnt cue-response. Alone these theories are insufficient, but the EI model of food craving (May et al., 2012) integrated these paradigms and extended the model to include elaborative cognitive processing and sensory mental imagery as key characteristics of food craving. In brief, the model suggests than external and internal sensory cues stimulate pleasurable thoughts of food (including planning to eat). However, mood drops due to the unpleasant awareness of the food deficit, which in turn, stimulates additional pleasurable food thoughts in order to rebalance mood. Thus, a vicious cycle of sensory imagery, cognition and emotion begins – thinking about a desired food is pleasant, but not having the food is unpleasant, so one thinks about the food more, and so on. Acquiring and eating the food breaks the cycle, and the resulting relief and pleasure of eating

reinforces the cycle of craving. Overall, the results of this study supported the EI model of food craving, demonstrating that internal thoughts of the food including sensory imagery, environmental sensory cues, negative affect and restriction of the craved food were all part of the craving experience, and that eating as a result of a craving was moderately pleasurable.

This study confirmed the importance of external and internal cues within food cravings. Food cravings were most often preceded by simply thinking about the food craved. However, there was no further elaboration on the content of these thoughts so it is not possible to compare to the prediction of the EI model which suggests these thoughts may consist of memories of the food, sensory imagery and planning to acquire the food. Less frequently, cravings were preceded by seeing or smelling the food and eating the food craved, and these factors influenced the intensity of the food craving. Additionally, patients identified mental imagery as part of their craving experience, including picture, smell, taste and texture, and these sensory images had a relationship with craving intensity. This is in line with the findings of Tiggemann & Kemps (2005) that picture, taste and smell are the predominant senses involved in food craving, and more vivid sensory imagery is positively correlated with craving intensity. Further to previous research, this study assessed not only sensory imagery in the moment of the craving, it also assessed participant's general propensity for mental imagery in everyday life. General mental imagery scores were not found to be related to craving experience. Unfortunately, the imagery questionnaire used focused solely on visual information and did not assess propensity to utilise other imagined sensory information such as smells, tastes and feeling. In a future study a broader measure of everyday use of sensory imagery could be employed to investigate the

potential relationship between ability to form mental imagery and intensity of food craving.

The EI model proposes that eating a craved food breaks the vicious cycle of craving, which suggests that having the food physically present might result in a craving which is more likely to be fulfilled. Conversely, the present study found that food cravings preceded by seeing or smelling the craved food were easier to resist. One explanation could be that the conscious awareness of access to the craved food may break the mental elaboration process of planning to acquire the food and limit the need to generate memory of the food and imagined sensory imagery, all of which would ordinarily intensify the craving experience. The limited cognitive processing required as a result of having the food present thus results in a craving lower in intensity, which is consequently easier to resist. However, considering the small sample size and statistical methodology, further research is required to investigate this finding.

One of the surprising results of the study was that scores of the intensity of food cravings recalled from the previous week were statistically higher than ratings given immediately after a food craving had occurred. The EI model highlights elaborative cognitive processing and the use of memories of foods in food craving. Considering the high likelihood of food consumption, and that food consumption leads to guilt and shame, it is possible that elaborative cognitive processing and memory storage of the craving event distorted the experience. Encoding the experience in memory as more powerful may help reduce any guilt associated with the incident. In addition, during future food cravings, these recollections of previous powerful and intense food craving experiences could be helping to drive contemporaneous experience.

Clinical relevance of findings

Bariatric surgery can be celebrated by the majority of recipients as an effective, life-changing operation; assisting those who have struggled to reduce their obesity to regain control over their eating. The resulting weight loss has multiple medical, social and psychological benefits for the majority of patients. However, a substantial proportion of patients struggle to maintain their weight loss and control their eating after surgery (Rusch & Andris, 2007) and a number of maladaptive eating styles have been observed (Conceiçao et al., 2014; Niego et al, 2007). Food cravings are a known trigger for maladaptive eating (Gendall et al., 1998), associated with lack of adherence to structured diets (Sitton, 1991) and increased number of failed weight loss attempts (Fabbricatore et al., 2013). Consequently, the understanding the phenomenology of food cravings generated by this study is an asset to people living with bariatric surgery, those considering surgery and the clinicians supporting them. Patients and clinicians should be aware that food cravings after surgery are commonplace and that most people fulfil their cravings very quickly after they are experienced. This information alone may help reduce the associated shame, guilt and stigma. However, the phenomenology of cravings can also guide patients and their clinicians to develop plans to cope with post-surgical food cravings. For example, the knowledge that food cravings are likely to occur in the early afternoon could help patients to plan an intervention for this time period. There are two key areas of clinical intervention – interventions to reduce the frequency of food cravings, and interventions to reduce eating in response to cravings.

Reducing the frequency of cravings would require reducing any factors that may trigger craving. In this study, food cravings were frequently preceded by thinking about food and the sight and smell of food. This highlights the ongoing importance of

reducing the pervasiveness of food and eating cues. For example, recent public health campaigns in the UK have reduced unhealthy food advertising on television aimed at children and removed high-sugar, high-fat convenience foods from tills in supermarkets. At a personal level, people struggling with post-surgical food cravings may consider reducing the number of food and eating cues they experience, such as moving commonly craved foods out of eye-sight in the home, or avoiding areas where they can smell tempting foods. Removal or avoidance of these stimuli may help to reduce the number of food cravings elicited. However, the majority of food cravings described in this study occurred without a direct physical stimulus and were instead driven by internal cognition. As a result, diminishing the power of the obesogenic environment will not be sufficient to prevent food cravings alone.

If reducing the triggers for food craving is difficult, then arming patients with techniques which help them to resist the craving are an alternative to reducing additional consumption of energy from food. Continued development of guided imagery and mindfulness-meditation interventions to limit the fulfilment of food cravings may prove useful. Guided imagery may interrupt the elaborative cognitive processes driving the craving, and ACT techniques including mindfulness meditation and cognitive defusion strategies can help patients to see themselves, their behaviour and their thoughts as distinct, thus assisting patients to cope with the thoughts of food without any subsequent eating behaviour. Previous studies testing ACT techniques have focused on chocolate and sweet cravings (Jenkins et al., 2013; Hamilton et al., 2014), so would need repeating to see if savoury targets are equally amenable to such interventions. One difficulty in producing an intervention may be the short space of time between the experience of craving and the eating response. Any intervention will need to be quickly accessible for patients if it is going to prevent eating. Having

successfully used web-based technology to study food cravings in this thesis, an app-based intervention (like the *Restrain* app under development at Cardiff University) could fit the bill. Integration of the typical phenomenology of post-surgical food cravings into the development of these interventions could help to develop a bespoke and targeted programme for people experiencing cravings after bariatric surgery.

Strengths and weaknesses of the methodology

CIA as a method for investigating food cravings

Research into food cravings can be broadly split along four main methodologies: one-off retrospective questionnaires, measurement of laboratory-controlled, experimentally-induced food cravings, EMA, and CIA. Retrospective food craving questionnaires such as the FCI record only the frequency and target of cravings recalled by the participant which is prone to memory biases and may be contributing to underreporting. Experimental methods are more suitable for researching using student participants due to the length of time required for the experimental procedure, and cravings are not contextualised in the natural environment. There has been some limited use of EMA methodology in which participants are asked to fill in surveys about their eating behaviour at either random or fixed-time points when prompted by a digital device. However it is unlikely that prompts from the device will coincide with a food craving in the moment so is more useful for recording general eating behaviours. Accordingly, this study utilised CIA methodology which allowed for the collection of phenomenological data during "hottest" moments of a food craving as they occurred, rather than collecting data about general craving and eating behaviour in any given moment. Use of CIA was a strength of the study as it resulted in a richer

and more detailed picture of food craving in the bariatric surgery population than existing research (e.g. Leahey et al., 2011).

Using web-based recording within CIA

One of the novel aspects of this research was the integration of web-based recording methods within the CIA methodology. The ubiquity of portable internet-enabled devices such as smartphones and tablets, and the common use of computers in everyday work and home life means web-based recording is a convenient and discrete method of data collection for participants. Half of the participants completed the study using this method, demonstrating its acceptability to the patient group which is only likely to increase over time with younger generations. For the researcher, web-based recording also had the benefit of ensuring all parts of the necessary questionnaire were completed in the correct way (by ensuring submission could only occur if all fields were completed in the right format). In a time-sensitive study such as this where participants were asked to fill out questionnaires in response to critical incidents, and at fixed time points (e.g. every evening), time-stamps on the web-based responses allowed the researcher to check that the protocol was followed correctly by the participant. Finally, the researcher and participant both benefitted from the data being immediately available – the researcher could check the responses were suitable and prompt the participant to return any missing data. Important, however, was the provision of choice to each participant. Not all participants were confident using internet devices or had the requisite technology to partake in this way, especially the older participants. Allowing the participants flexibility to use the method that suited their lifestyles best maximised participation in the study. One possibility for improving this method in future could be the development of a bespoke app which

could be programmed to provide prompts for the fixed data collection points e.g. on an evening to remind participants to complete the end of day questionnaire.

Sampling

The study focused on a small sample (although double the number who participated in Guthrie et al., 2014) of the clinical cohort, with only 12% responding to the postal advertisement of the study. However, postal recruitment methods have a notoriously low uptake rate and this uptake rate is not unusual. For example, Hughes-Morley, Young, Hempel, Russell, Waheed & Bower (2016) reported a 13% response rate using postal recruitment from GP records. Furthermore, this study accepted participants up to ten years after surgery using records from a clinical database that included people who had not been seen within clinic for up to nine years previously. This was a strength of the research, as the majority of previous studies included patients up to only five years after surgery. However, the length of time after the surgery and follow-up presented a problem for recruitment. A substantial proportion of these potential participants within the clinical records may have changed their address or name, been deceased, had their surgeries reversed or had other life circumstances that prevented their participation. Nevertheless, postal recruitment methods were preferred for the following reasons. The standard procedure within the clinics meant patients did not attend the clinic after 12-24 months of follow-up, and past this time point would only make contact with the clinic if things were not progressing well or there were complications from the surgery. Whilst Guthrie et al (2014) recruited patients from an online weight-loss support organisation, this was discounted as a recruitment method as to ensure accuracy of the surgical and weight data which could be obtained from clinic records. Postal recruitment ensured that patients with a range of post-surgical experiences were recruited rather than patients

who sought additional support (from clinic or support forums). Indeed, the sample included participants who did not report any food cravings but still wished to share their experience. This is promising as Hughes-Morley et al (2016) concluded that potential participants decline postal recruitment for four reasons: they decline all studies regardless of subject or method, they self-exclude based on their assessment of the eligibility criteria, they see no benefit to taking part, or they anticipate potential negative consequences of taking part. As the recruitment materials referred to experience of food cravings, some participants may have self-excluded if they did not identify with experience of food cravings. Future recruitment materials might be altered to clearly state that experiences of people who both do and do not feel they experience cravings are equally valued.

Around 10% of participants dropped out of the study. This could be attributed to two factors: firstly, participants may not have realised the extent of the recording involved or found the method of recording difficult. Secondly, the research area may have been emotive subject for some participants. However it is a much lower dropout rate than reported by Guthrie et al. (2014) where over 35% did not return their questionnaires. Two methodological differences may account for this higher retention rate: firstly, participants needed to opt-in to the present study after reading the materials (which indicated high motivation to take part) and the materials sent care of their surgery provider (whom participants may have been motivated to assist). In comparison, Guthrie et al (2014) approached participants within a clinic (who may have assented to the study due for social reasons) and recruited from an online forum (where patients had no personal connection to the study). Secondly, participants were offered two methods of completion which may have improved the ease of

participation. However, it is difficult to know what factors contributed to participant uptake and drop out with certainty.

During the telephone screening phase participants were asked to declare any additional medical conditions or medications. Whilst efforts were made to exclude participants where it was felt the medical condition or medication was the primary factor in eating and appetite behaviour, this relied solely on participant report. As such, the influence of other medical conditions (diagnosed and undiagnosed) or secondary effects of medications cannot be ruled out.

The study sample was predominantly female and the majority had received RYGB. This gender imbalance is unsurprising as a recent UK cohort study showed 80% of people receiving bariatric surgery were female (Douglas et al., 2015). However, fewer LAGB and LSG procedures were represented in the study compared to surgical prevalence rates reported by Douglas et al (2015). As this study took place within one city in the UK and included only a small number of surgeons, the RYGB-bias might be attributable to the regional and surgical speciality of the recruiting clinics. On the other hand, it could reflect a difference in the lived experience of people with different surgeries which affected motivation to participate in the study. To investigate this more fully in future research, surgeons could be recruited based on their surgical specialisms to ensure patients are recruited from different surgical groups and data collected on the uptake rates from different surgical types. To allow for comparisons of surgeries, the sample could be stratified to include equal numbers of participants from each surgical group.

Previous research had indicated that a significant minority of patients did not achieve or maintain weight loss after surgery (Budak & Thomas, 2009; Benotti &

Forse, 1995) but this cohort of patients did not appear to be represented in the study sample. All the participants had achieved a weight and BMI reduction compared to their pre-surgical weight. However, as this study excluded participants who had additional serious medical complications affecting appetite or eating and those who had received more than one type of bariatric surgery, this may have excluded patients with poorer weight and BMI outcomes. In addition, patients who had not achieved their desired outcomes may be less likely to volunteer in research. On the other hand, this study only compared pre-surgical weight and BMI with current figures and did not look at weight/BMI change over time. Therefore it is possible that some participants, whilst still weighing less than they did pre-surgically, have regained some weight compared to their lowest measurement, or that their weight has fluctuated over time. Furthermore, current weight was self-reported and so may have been prone to underreporting bias.

Data analysis

In addition to the sampling issues, the nature of the collected data challenged the analysis. The CIA methodology allowed for multiple recordings of food cravings to be submitted by each participant (or conversely, none at all), thus violating the assumption of independence and making group comparisons problematic. Whilst Guthrie et al. (2014) chose to use parametric and non-parametric comparison of means tests (e.g. t-tests, analysis of variance), the authors acknowledged the flaws in their analysis in the discussion and suggested regression could have been more appropriate. This thesis used data-driven decision trees to look for how the data clusters, and mixed-model analysis to conduct an exploratory analysis of possible relationships between food cravings, mood, eating behaviour and imagery whilst accounting for the issue of repeated recordings.

Decision trees are a simple and effective way of representing patterns in a large dataset, and inclusion of participant ID allows for the influence of the participant to be considered. However, the output of the decision tree is controlled by the researcher who can set the number of cases within the modes, and the number of levels in the tree until arriving at what seems to be the best fit which can lead to potential overfitting of the data. Accordingly, the results of the decision trees should be cautiously considered as indicators of possible relationships which require confirmation through additional research.

Mixed-models analyses were selected as they are used for non-independent data and accounted for the fixed effects of the measured variables, alongside the repeated, random effects of the participant. Additionally, mixed-models are extremely flexible; coping with binomial data and non-normal distributions. With a large number of possible influencing variables and an exploratory study with little previous research to drive directional hypotheses, a backwards, stepwise procedure was considered the most appropriate method of fitting the variables to the model. Use of this backwards, stepwise procedure can be considered controversial as the inclusion of all possible variables from the outset can lead to the inclusion of significant results which are due to chance. Again, the results of the mixed-models analyses should be considered with caution and used as a starting point for future research rather than considered definitive.

Alongside the structured questionnaires, participants were given the opportunity to provide free-text responses as they wished. These responses were checked for useful information about the responses to ensure food cravings were not interpreted out of context. For example, they revealed that most reports of night-time cravings came from participants working on night shifts. However, some participants used to

free-text fields to give detailed feedback on their experiences of living with bariatric surgery, their eating and/or their food cravings. It was beyond the scope of this project to conduct any analysis using these free text responses.

Defining food cravings

Food cravings are a subjective, psychological experience and therefore are difficult to define. For the purposes of this study, a food craving was defined as *"an intense desire for a specific food or food group"* which was consistent with Guthrie et al. (2014). Although this definition was given to participants, they were largely able to self-define what they believe constituted a food craving experience. Participants completed a food craving record whenever they experienced what they would consider a food craving, and this may have differed from person-to-person. Use of an alternative definition, for example emphasising the intensity or specificity of the craving, may have changed the frequency of the reports received during the study, as shown by Gendall, Joyce & Sullivan (1997). Furthermore, definition by craving target followed a previous classification based the predominant flavour of the food – sweet, savoury, chocolate and a catch-all "other" group (Hill et al., 1991) which was consistent with previous research (Guthrie et al., 2014). However, alternative taxonomies could be used based on other salient sensory information of the craving such as the texture (e.g. crunchy/crispy, soft, chewy) or the predominant nutrient content (e.g. fat, sugar, carbohydrate, protein) or combinations (e.g. sweet carbohydrate, savoury carbohydrates as in Christensen & Pettijohn., 2001). It could be that a more detailed analysis of the free-text comments might have identified which predominant aspect of the food was being craved and a taxonomy been built from the data.

Directions for future research

A first port of call for future study could be to conduct additional analyses on the data already collected during this project. A future development could examine the free text responses using a qualitative method (e.g. content analysis) to look for prominent themes in how patients report their experience. Secondly, the meal pattern questionnaire could be examined to look at eating patterns and frequencies of meals – firstly to assess whether reported eating pattern within the daily diaries correlated with self-reported eating pattern and grazing in the background questionnaires, and secondly, whether meal pattern and frequency was related to craving. For example, do those who eat regular meals and snacks experience fewer cravings than those who eat in a less regular pattern?

One of the limitations of this study was the relatively small sample size, but a sister project using the same methodology is underway. A second cohort of post-surgical bariatric patients have been recruited alongside two non-surgical comparison groups: a group of participants with healthy BMIs and a group of participants with overweight BMIs who are dieting. Merging the samples to create a larger cohort of patients to study will not only provide the basis for a more powerful phenomenology of food cravings, but furthermore this new study is using an different recruitment source with the aim of recruiting more participants with LAGB and LSG to conduct a more meaningful comparison of surgical types. Furthermore, comparisons will be made with the non-surgery groups to further explore the role of dieting and weight/BMI on food craving experience. It might also be possible to use a cluster analysis to look for groups of participants who, for example, report cravings but are consistently able to resist them, versus those who report cravings who find cravings irresistible, versus those who report very few or no cravings – and identify what sets

these groups of participants apart: the craving target, their surgery, their psychological characteristics or something else?

One of the difficulties of this area of research is attributing the differences in food cravings to the result of the surgery and/or the specific surgical procedure rather than observation that people who receive the surgeries could represent a distinct cohort of people. The By-Band-Sleeve Trial offers an exciting opportunity for future research. Randomising participants to surgical type eliminates the influence of location, patient and surgeon preference are and so provides an ideal cohort of patients from which to recruit a larger, more surgically diverse sample for a repeat study. To further untangle the multitude of influencing factors on control of eating and food cravings in the surgical population, a longitudinal study could be conducted that tracks people with obesity who later receive surgery for number of years post-surgery, alongside people with obesity who do not receive surgery. Such a longitudinal study would record any variation in cravings over time alongside any fluctuations in weight and BMI. As discussed earlier, this study did not appear to recruit patients who regained significant amounts of weight after surgery and it is possible this group was experiencing food cravings in a markedly different way to those who do maintain their weight loss. Capturing the experience of this cohort in a future study is important, especially as these are the patients may require the greatest help to regain control of their eating and their weight.

One area missing from this study, and from many others, is the cognitive and emotional appraisal of the food craving experience itself. For some participants, food cravings might have been experienced as a fairly benign phenomena, for others an unwelcome irritant, and for some associated with high level of remorse, shame and self-criticism. A study which investigated how patients perceive and interpret the

experience of food craving and how this relates to fulfilment of craving, eating pattern, disordered eating and weight change might uncover an important mediator of craving experience and control of eating. Maybe the important question is it not how often or what you crave, but what the craving *represents* to you that makes a critical difference in eating control.

Finally, a small number of participants discussed drink cravings during the recruitment conversation. As this study focused solely on food cravings, participants were asked solely to report and describe their food cravings. Recent reports suggest some people with bariatric surgery have an elevated rate of alcohol consumption (Spadola et al., 2015; King et al, 2017). As increased alcohol intake results in greater calorie intake and increases the risk of alcohol-associated health conditions and weight gain, consideration of the role of drink cravings could be important. A simple adaptation of this study procedure could be made to include reporting of drink cravings in addition to food cravings.

CONCLUSION

The rising rate of obesity is an unprecedented health challenge and simple strategies of weight management which encourage individuals to “eat less and move more” have not been entirely effective. The literature suggests the process of developing obesity is more complex than initially thought, involving a number of biological, psychological, familial and societal factors which affect an individual’s predisposition to accumulate weight and the ability to control eating behaviour. When obesity becomes severe, bariatric surgery is an effective physical intervention to reduce weight and BMI. However, recent research shows many bariatric patients struggle to regulate their eating behaviour long-term, typically engaging in maladaptive grazing and binge-eating behaviours. Such uncontrolled eating can lead to some patients to regain their lost weight. Furthermore, several different forms of surgery are offered and there is conflicting evidence as to which procedure has the best outcomes in terms of weight loss and associated eating behaviour. If we are to find a way of managing obesity, it is critically important that we improve our understanding of what factors affect eating control. A growing body of evidence implicates food cravings in the development of maladaptive eating patterns, disordered eating, difficulties adhering to diet plans and the development of obesity. However, evidence for how food cravings are experienced by people who have received bariatric surgery is limited. This study is the first to provide a detailed description of the experience of real-life, contemporaneous food cravings in those living with bariatric procedures up to ten years after their surgery. The findings show that patients and clinicians should expect and plan for the experience of food cravings after surgery, and that most cravings will result in eating if not managed. This commonality of experience should be of some comfort to those who are ashamed or guilty of their craving-related eating behaviour. Furthermore, the detail

provided in studies of food craving phenomenology points to strategies people engaged in weight management – not just those who have received bariatric surgery – may use to disrupt strong urges to eat. The findings of this study add the body of evidence demonstrating how external sensory cues and internal imagery are key parts of the craving phenomenology. Psychological strategies such as guided imagery, cognitive defusion and mindfulness have been demonstrated to reduce food craving by interrupting the cognitive, emotional and sensory processes that underpin craving. Given the rise in use of web-based and digital technologies, the incorporation of these strategies into app-based intervention programmes may offer an instantly-available and cost-effective way of helping people reduce the likelihood of eating in response to craving and thus improve control of eating.

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Appendix A: Study Measures

A1. Food craving record

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Food Craving Record

Please complete a new record every time you have a food craving, regardless of whether or not you eat. Please answer every question.

1. Your name:……

2. What food were you craving exactly?.....

3. Date of craving: ……

4. At what time did the craving begin:……

5. **Immediately before** the craving did you… (circle any that apply)
   - See or smell the food craved
   - See or smell other food
   - Simply think about the food craved
   - Simply think about other food
   - Eat the food craved
   - Eat other food
   - None of these

6. How hungry were you **immediately before** the craving? (Please tick one)

0 Not at all hungry	1	2	3	4	5	6	7	8	9	10 Extremely hungry

7. How **strong** was the food craving? (Please tick one)

0 Not at all strong	1	2	3	4	5	6	7	8	9	10 Extremely strong

8. How **difficult** was the food craving **to resist**? (Please tick one)

0 Not at all difficult	1	2	3	4	5	6	7	8	9	10 Extremely difficult

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9. Recently how much have you tried to **restrict** eating this food? (Please tick one)

0 Not at all restricted	1	2	3	4	5	6	7	8	9	10 Extremely restricted

10. During the craving, how **vividly** did you **picture the food in your mind**? (Please tick one)

0 Not at all vividly	1	2	3	4	5	6	7	8	9	10 Extremely vividly

11. During the craving, how **vividly** did you **imagine its taste**? (Please tick one)

0 Not at all vividly	1	2	3	4	5	6	7	8	9	10 Extremely vividly

12. During the craving, how **vividly** did you **imagine its smell**? (Please tick one)

0 Not at all vividly	1	2	3	4	5	6	7	8	9	10 Extremely vividly

13. During the craving, how **vividly** did you **imagine how it would feel in your mouth or throat**? (Please tick one)

0 Not at all vividly	1	2	3	4	5	6	7	8	9	10 Extremely vividly

14. Did you eat as a result of this craving? YES or NO (please circle)

    a. If **NO** – What did you do instead? ……
    Please skip to question 16.

    b. If **YES** – please answer question 15.

End of Day Questionnaire

Please fill in this survey at the end of each day. Read each item and choose the answer which best represents your experience over the day. Please answer every question.

1. Please write your name: ……

2. Date of questionnaire: ……

3. How **anxious** have you felt today? (Please tick one)

0 Not at all anxious	1	2	3	4	5	6	7	8	9	10 Extremely anxious

4. How **easy have you found it to control your eating** today? (Please tick one)

0 Not at all easy	1	2	3	4	5	6	7	8	9	10 Extremely easy

5. How **content** have you felt today? (Please tick one)

0 Not at all content	1	2	3	4	5	6	7	8	9	10 Extremely content

6. How **hungry** have you felt today? (Please tick one)

0 Not at all hungry	1	2	3	4	5	6	7	8	9	10 Extremely hungry

7. How **tense** have you felt today? (Please tick one)

0 Not at all tense	1	2	3	4	5	6	7	8	9	10 Extremely tense

8. How **irritable** have you felt today? (Please tick one)

0 Not at all irritable	1	2	3	4	5	6	7	8	9	10 Extremely irritable

A2. End of day questionnaire

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15. Please describe in detail what you ate ……

    a. How long did you resist the craving ……(minutes/hours)

    b. How **pleasant** was the taste of what you ate? (Please tick one)

0 Not at all pleasant	1	2	3	4	5	6	7	8	9	10 Extremely pleasant

16. Having experienced the food craving, how **quickly** did it vanish? (Please tick one)

0 Not at all quickly	1	2	3	4	5	6	7	8	9	10 Extremely quickly

17. If there is anything else you wish to tell us about this food craving, please do so in this space below (Optional).

Many thanks for completing this survey. Please keep hold of this survey and return it to the researcher at the end of the study week.

9. How **strong was your desire to eat** today? (Please tick one)

0 Not at all strong	1	2	3	4	5	6	7	8	9	10 Extremely strong

10. How **bored** have you felt today? (Please tick one)

0 Not at all bored	1	2	3	4	5	6	7	8	9	10 Extremely bored

11. How **often have you had food cravings** today? (Please tick one)

0 Not at all often	1	2	3	4	5	6	7	8	9	10 Extremely often

Note: If you experienced any food cravings today, please make sure you have completed a Food Craving Record for each craving.

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Your eating patterns today

12. Consider the past 24 hours. Please note any occasion you have had a meal, snack or drink (excluding water). There is likely to be many of these. Work down the grid, hour by hour, and **tick** for any eating episode.

Main meal: cooked dish, soup with bread, salad with bread, pizza, pasta etc.

Light meal: breakfast cereal, sandwich, soup, salad, omelette etc.

Snack: Toast, biscuit, cake, fruit, sweets, ice cream etc.

Drink: Coffee/tea, soft drinks, milk, juice, beer, wine, spirits etc.

Time:	Main meal	Light meal	Snack	Drink
12.00 am midnight				
1.00 am				
2.00 am				
3.00 am				
4.00 am				
5.00 am				
6.00 am				
7.00 am				
8.00 am				
9.00 am				
10.00 am				
11.00 am				
12.00 pm midday				
1.00 pm				
2.00 pm				
3.00 pm				
4.00 pm				
5.00 pm				
6.00 pm				
7.00 pm				
8.00 pm				
9.00 pm				
10.00 pm				
11.00 pm				

Many thanks for completing this survey. Please keep hold of this survey and return it to the researcher at the end of the study week.

Background Information Questionnaire

Taking part in this study involves answering a few background questions about yourself, your eating and eating patterns, and your mood. Please work through these questions which should take you around 15 minutes to complete. Please answer all questions.

If you have any concerns or questions whilst answering these questions, please contact the researcher.

Section one: Some information about you and your health.

1. What is your name? ……
2. What is your home postcode? ……
3. What is your date of birth? ……
4. Are you MALE or FEMALE (please circle)
   a. If FEMALE, are you currently pregnant? YES or NO (please circle)
5. What is your height? ……
6. What is your current weight? ……
7. Do you have any health conditions for which you are taking medication? (please circle)
   a. None
   b. Diabetes Type 1
   c. Diabetes Type 2
   d. Hypertension (high blood pressure)
   e. Angina (chest pain)
   f. Cholesterol
   g. Mood difficulties
   h. Chronic pain
   i. Other……

What is the name of the medication you are taking? ……

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Section Two: About your most recent food craving

8. Have you had a food craving in the **past seven days**? YES or NO

If NO – Please skip to Section Three.

If YES – Please answer the following questions:

a. Which one food have you been mainly craving for? ……

b. Thinking just about this one food, how **strong** have the cravings been for this food?

0 Not at all strong	1	2	3	4	5	6	7	8	9	10 Extremely strong

c. Thinking just about this one food, how **difficult has it been to resist eating** this food?

0 Not at all difficult	1	2	3	4	5	6	7	8	9	10 Extremely difficult

d. In your mind, how **clear and detailed** was the **image of the food** at the time you had your craving?

0 Not at all clear and detailed	1	2	3	4	5	6	7	8	9	10 Extremely clear and detailed

e. In your mind, how **clear and detailed** was the image of you eating the food at the time you had your craving?

0 Not at all clear and detailed	1	2	3	4	5	6	7	8	9	10 Extremely clear and detailed

f. How **easy** is it to visualise this food in your mind **right now**?

0 Not at all easy	1	2	3	4	5	6	7	8	9	10 Extremely easy

Section Three: Your eating pattern

9. How much do these statements describe your eating behaviour in the **past seven days**? (Please tick one per row)

	Never	Rarely	Sometimes	Most of the time	All the time
I have grazed between meals (eaten repeatedly small quantities of foods)					
I have eaten more or less continuously throughout the day or for extended parts of the day (e.g. all afternoon)					
I have eaten in an unplanned and repetitious way (e.g. eaten between planned meals and snacks)					
I found myself picking or nibbling at food continuously					
I felt compelled or driven to eat even when not hungry					
I felt unable to stop grazing					
I felt I lost control over my eating while grazing					

10. Which of the following best describes your eating patterns over the **past seven days**? (Please tick one)

Planned and controlled eating. Having small amounts of food throughout the day. Choosing what foods to eat and controlling the overall amount eaten.	
Deliberately overeating. Repeatedly having small amounts of food with the intention of eating large amounts. Dividing large meals into separate courses in order to overeat	
Grazing but in control. Mindlessly eating or eating in a distracted way. Eating whatever is available, on the spur of the moment.	
Grazing but out of control. Trying to resist foods but going back to eat small or modest amounts. Eating what is most tempting in that moment. Responding to urges to eat.	
Binge eating. Feeling that you can't stop eating after starting. Feeling out of control over eating. These are binge eating episodes rather than eating repeatedly and all the time.	

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Section Four: Your feelings about eating, body shape and weight.

11. How well do these statements describe your eating behaviour over the **past seven days**? (please tick one per row)

	Definitely true	Mostly true	Mostly false	Definitely false
I start to eat when I feel anxious				
When I feel sad, I often eat too much				
When I feel tense or "wound up," I often feel the need to eat				
When I feel lonely, I console myself with food				
If I feel nervous, I try to calm down by eating				
When I feel depressed, I want to eat				

12. On how many of the **past 28 days**.... (please tick one per row)

	None	A few days (1-5)	Less than half (6 – 12)	Half the days (13- 15)	More than half (16-22)	Most days (23-27)	Everyday
I have consciously tried to **restrict the amount of food** I eat to influence my weight or shape							
I have attempted to **avoid eating any foods I like** in order to influence my weight or shape							
I have attempted to **follow definite rules** about eating in order to influence my weight or shape*							

*e.g. set a calorie limit or made rules about when and what you can eat.

13. Over the **past 28 days**..... (please tick one per row)

	0 Not at all	1	2	3	4	5	6 Extremely
How often had your **weight** influenced how you think about (judge) yourself as a person?							
How often had your **shape** influenced how you think about (judge) yourself as a person?							
How dissatisfied have you felt with your **weight**?							
How dissatisfied have you felt about your **shape**?							

14. Over the **past 28 days**, how many times have you eaten what other people would regard as an **unusually large amount of food** (given the circumstances)?

Please give a number here……

a. And on how many of these times did you have a sense of having **lost control** over your eating (at the time you were eating)?

Please give a number here……

Section Five: Your mood and bodily sensations

15. How have you felt over the **past seven days**? (please tick one per row)

	Not at all	Some of the time	A good part of the time	Most of the time
I was aware of dryness in my mouth				
I couldn't seem to experience any positive feeling at all				
I experienced breathing difficult (e.g. excessively rapid breathing/breathlessness in the absence of physical exertion)				
I found it difficult to work up the initiative to do things				
I experienced trembling (e.g. in the hands)				
I was worried about situations in which I might panic and make a fool of myself				
I felt I had nothing to look forward to				
I felt down-hearted and sad				
I felt I was close to panic				
I was unable to become enthusiastic about anything				
I felt I wasn't worth much as a person				
I was aware of the action of my heart in the absence of physical exertion (e.g. sense of heart rate increase or heart missing a beat)				
I felt scared without any good reason				
I felt that life was meaningless				

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Section Seven: The pictures in your mind

16. How much do each of these descriptions describe your usual experience? (please tick one per row)

	1 Never	2	3 Half the time	4	5 Always
When going to a new place, I prefer directions that include detailed descriptions of landmarks e.g. the shape and colour of a petrol station, in addition to their names					
If I catch a glimpse of a car that is partially hidden behind bushes, I automatically "complete it", seeing the entire car in my mind's eye.					
If I'm looking for new furniture in a shop, I visualise what the furniture would look like in particular places in my home					
I prefer to read novels that lead me to easily visualise where the characters are and what they are doing, instead of novels that are difficult to visualise					
When I think about visiting a relative, I have a clear mental picture of him or her					
When relatively easy technical material is described clearly in writing, I find illustrations distracting as they interfere with my ability to visualise the material					
If someone were to tell me two-digit numbers to add e.g. 24 plus 31, I would visualise them in order to add them					
Before I get dressed to go out, I first visualise what I will look like if I wear a different combination of clothes					
When I think about the list of things to buy, I visualise the shops I will need to visit					
When I hear a friend's voice, a visual image of him or her springs to mind					
When I hear a radio announcer or DJ I have never actually seen, I find myself picturing what they might look like					
If I saw a car accident, would visualise what has happened when later trying to recall the event					

And finally…. Your opportunity to tell us more.

If you would like to write any additional comments about your food cravings (or your eating behaviour since your bariatric surgery, please do so on this page.

Many thanks for completing this survey. Please keep hold of this survey and return it to the researcher at the end of the study week.

Appendix B: Study information sheets

B1. Participant information sheet

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Control of eating after bariatric surgery

Participant information sheet

You are being invited to take part in a research study.

Before you decide if you would like to take part, you should understand why this research is being done and what it will involve. Please take some time to read through this information carefully.

What is this study for?

This study is looking at people's ability to control their eating after they have had weight-loss surgery. In particular, we want to know about any experiences you have of craving foods. A food craving is when you have an intense desire for a particular food which cannot be satisfied with anything else. We are also investigating if people who have different types of weight-loss surgery (e.g. gastric bands, gastric bypass etc.) experience food cravings differently. In addition, we'd also like to know about the mental imagery (i.e. the pictures in your head) during cravings, your eating patterns and your mood more generally.

This research will help us understand more about how people control their eating after weight-loss surgery which will help services provide better care for people in the future.

What does this research involve?

Firstly, you will be asked to complete several questionnaires about your eating behavior, your mood, as well as providing some information about yourself such as the type of surgery you have had, how long ago the surgery took place, and your weight before and after surgery. These questionnaires will take you around 20 minutes to complete.

Following this, you will be asked to monitor your food cravings over a period of seven days. If you experience a food craving, you will need to fill out a short survey about the experience as soon as possible after the craving happens. This should only take a couple of minutes to do. Finally, at the end of each of the seven days, you will need to complete a brief questionnaire about how you felt during the day and what time you ate your meals. Again, this will only take a couple of minutes.

I will contact you by telephone at the beginning of the week to give you all the instructions and answer any questions you have. We can also meet face-to-face so I can talk you through the instructions in person, either at University of Leeds or at your home if convenient. I will also give you my contact details so you can talk to me during the week if you have any problems. I will also send you an email three days into the week to see how you are doing.

It is your choice whether you complete the questionnaires using your smartphone, tablet or computer, or you use paper questionnaires. We would ask you to use the method which fits your lifestyle best. If you wish to complete the forms on paper, I will send them to you in the post and provide a stamped, addressed envelope for you so you can return them to me at the end of the week.

We will also need some information about the type of surgery you had and when, and your weight before and after the surgery. We will get this information from your care team at St James' University Hospital. One of the clinical staff will enter your medical record, retrieve this data, make it anonymous by removing your name, then send it to the researcher via email. The researchers will not access your medical records at any time.

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Who has reviewed this study?

This study was reviewed by East of England – Essex Research Ethics Committee (REC reference ID:17/EE/0252 who confirmed it met ethical standards on 10/07/17. It has also been reviewed by and registered with the Leeds Teaching Hospitals NHS Trust Research and Development department (ID: GA17/95163).

Why have I been chosen to take part?

We are inviting patients who have received weight-loss surgery between one and ten years ago from the following surgeons to take part: Mr Abeezar Sarela, Mr Simon Dexter, Mr Stephen Pollard, Mr Jeremy Hayden or Mr Sam Mehta. Both NHS patients and private patients can take part.

What will happen to the information you collect?

We follow strict rules and procedures to keep all your data secure and confidential. The online questionnaire will store your data in a secure, confidential manner in a system called Bristol Online Survey. Paper questionnaires and consent forms will be stored in a locked filing cabinet at the Institute of Health Sciences, University of Leeds and destroyed at the end of the study. All the data from both the paper and online questionnaires will be inputted into a secure computer database held at the University of Leeds and statistically analysed. Anonymous copies of the data will be kept for three years after the study ends then destroyed in accordance with the Data Protection Act.

The information we collect in this study will be presented as part of a Doctorate in Clinical Psychology at the University of Leeds. If I use quotations, these will be completely anonymized and will not contain anything which might identify you individually. A summary of the research will be sent to everyone who takes part at the end of the study.

Do I have to take part? What if I change my mind?

You do not have to take part. It is up to you to decide whether you wish to take part or not. Your future care will not be affected by your decision to take part or not.

You are free to withdraw at any time during the study. You can contact me and let me know you have changed your mind. I will remove your data from the study and destroy any information I hold about you. Your future care will not be affected if you decide to stop taking part in the study.

Once the data is analysed, it will not be possible to remove your data. This is scheduled to begin Spring 2018. If you contact me to withdraw your data after data analysis has started, I will inform you if this is not possible.

Where can I get further information?

If you have any questions about this study, you are welcome to contact me and I will answer your questions via email, telephone, or we can arrange a face-to-face meeting if you would find it helpful.

The best way to contact me is via email: umkp@leeds.ac.uk. I am also available during office hours (Mon – Fri, 09:00 – 17:00) by telephone: 0779 220 8815.

If you wish to make a complaint about this study, please contact: Clare Skinner, Faculty Head of Research Support, Faculty of Medicine and Health Research Office, Room 9.29, Level 9, Worsley Building, University of Leeds, Clarendon Road, Leeds, LS2 9NL.

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Control of eating after bariatric surgery

Consent form

Researcher: Kathryn Palmer, Trainee Clinical Psychologist, University of Leeds

Research Supervisors: Professor Andrew Hill and Dr Gemma Travis-Turner, University of Leeds.

Please read the following information and initial the box next to it to confirm you agree.

	Initial here
1. I confirm I have read and understood the information sheet (dated 16/06/2017) for the above study. I have had the opportunity to consider the information, ask questions and have these answered satisfactorily.	
2. I understand that my participation is voluntary and I can free to withdraw at any time without giving a reason. Withdrawing will not affect my future care or legal rights	
3. I understand that the researcher may use anonymized direct quotations in publications arising from this study.	
4. I understand that relevant sections my medical notes and data collected during the study may be looked at by individuals from University of Leeds, from regulatory authorities or from the NHS Trust where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records.	
5. I understand that the information collected about me will be used to support other research in the future, and may be shared anonymously with other researchers.	
6. I agree to take part in this study.	

Name: (BLOCK CAPITALS) .....

Signature: ..... Date: .....

Please provide a telephone number so I can call you and provide you with details of the study:

Preferred telephone number:

Alternative telephone number (optional):

Please provide an email address so I can send you more information about this study:

Email address:

Please indicate the best time of day to contact you by telephone:

Morning (9:00 to 12:00) ☐ Afternoon (12:00 to 17:00) ☐ Evening (17:00 – 19:00) ☐

Please return this form to the researcher using the envelope provided.

B2: Participant consent from

I want to take part in the study. How can I get involved?

Enclosed with this letter is a consent form. If you have any more questions or queries about this study or the consent form, please contact me for more information. Once you are satisfied, you can sign the enclosed consent form, complete the section detailing the best method of contacting you, then return the form using the stamped, addressed envelope provided. Once I have received the consent form, I will contact you to give you further instructions.

If you are not interested in taking part, you do not need to do anything.

Thank you for taking the time to read this information. Please contact me with any queries.

Best wishes,

Kathryn Palmer
Researcher and Trainee Clinical Psychologist
Email: umkp@leeds.ac.uk Tel: 07792208815 (Mon- Fri, 09:00 – 17:00)
Institute of Health Sciences, Level 10, Worsley Building
University of Leeds, Clarendon Way
Leeds, LS2 9NL

B3: Study instructions

Dear participant,

CONTROL OF EATING AFTER BARIATRIC SURGERY (IRAS STUDY ID: 219652)

STUDY INSTRUCTIONS AND INFORMATION

Thank you for agreeing to take part in this research study. This email will contain all the information you need to take part. If you get stuck during your study week, please refer to this email as it might help you.

INTRODUCTORY APPOINTMENT:

You will have an introductory appointment with Kathryn Palmer, Lead Researcher, either via telephone or face-to-face. During this appointment, you will be instructed on how to fill out the background questionnaires. After this, you will identify a seven-day period when you will take part in the study. This is called your "study week."

For this study week, we would like you to monitor your eating habits, experiences of food craving and mood for seven days. It should be a "normal" week for you. You do not need to do anything to change your eating or mood during this study week, simply report what you experience naturally. It is up to you when you decide to do your seven-day study week – just let Kathryn know so she can support you through the week.

INSTRUCTIONS FOR STUDY WEEK:

- During your study week, we would like you to pay attention to any **food cravings** you experience. A **food craving** is when you have an intense desire for a certain food or food group.
- If you notice you have a food craving, please fill out some information about that craving on the **Food Craving Record as soon as possible after you notice the craving.** You can access this record by clicking this link: [weblink] or completing your paper copy.
- If you only realize you had a food craving later, or forget to fill out the Food Craving Record, that's OK. Just fill out as much as you remember on the Food Craving Record.

- At the end of each day of the study week, please fill out the **End of Day Questionnaire**. You can do this by clicking this link: [weblink] or completing your paper copy.
- Three days into your study week, I'll send you an email or telephone you to see how you are doing.
- At the end of the seven days, you can stop filling out the forms. I will contact you via email or telephone to thank you for taking part.

ACCESSING THE ONLINE QUESTIONNAIRES:

To make it easy for you to complete the questionnaires during your day-to-day life, you can access the questionnaires online and save the links to your smartphone or tablet. Instructions on how to do this are attached to this information pack**.**

Please note: these questionnaires are hosted on an internet site. Therefore, you must be connected to the internet to complete these questionnaires.

If you choose to complete these questionnaires using your smartphone whilst on-the-go, this could use some of your mobile data. If this is a concern for you, please only complete the questionnaires via a desktop internet connection or when connected to Wi-Fi. Paper and pencil copies of the questionnaires can be requested from the researcher if you would rather not fill out the internet questionnaires.

CONTACTING THE RESEARCHER:

If you have any problems or concerns, please feel free to contact Kathryn using these details:

Email: [EMAIL ADDRESS]

Telephone: [TELEPHONE NUMBER] (Mon – Fri, 09:00 – 17:00)

Many thanks again for agreeing to take part in this study.

Best wishes,

Kathryn

Kathryn Palmer, Psychologist in Clinical Training and Lead Researcher, University of Leeds

Appendix C: Correlation tables

Table C1.

Pearson correlations between background variables and key characteristics of food craving.

	Craving intensity	Craving resistibility	Sensory score	Hunger	Restriction	See/smell food	Think about food	Eat food
Age	0.31*	0.09	-0.11	0.49	0.36*	0.13	0.23	0.33*
Current BMI	-0.18	-0.19	-0.29	-0.26	-0.13	0.06	-0.13	-0.10
Months since surgery	-0.03	-0.22	0.22	0.33*	0.02	-0.07	0.21	0.01
DASS Anxiety	0.02	-0.16	0.01	-0.03	0.12	-0.21	0.10	-0.03
DASS Depression	-0.06	-0.21	-0.05	-0.06	0.07	-0.28	0.19	-0.12
EDE-Q Restriction	-0.14	-0.05	-0.19	-0.14	-0.15	0.06	0.14	-0.22
EDE-Q Overvaluation	0.04	-0.20	0.08	-0.15	0.19	-0.20	0.20	-0.16
EDE-Q Dissatisfaction	-0.01	-0.13	-0.22	-0.26	-0.06	0.05	0.04	-0.32*
SUIS	0.41**	-0.27	0.30*	0.11	0.38*	-0.23	0.26	0.25
TFEQ	-0.05	-0.19	0.10	-0.16	0.04	-0.06	0.03	-0.12
Grazing	0.07	-0.11	0.06	0.32*	0.01	-0.22	0.04	0.09

** p< 0.05 **p< 0.01*

Table C2.

Pearson correlation of fixed effects which predict craving intensity

	Think about food	See/smell food
See/smell food	0.34*	
Eat food	-0.14	0.01

** p< 0.05*

Table C3.

Pearson correlation of fixed effects which predict craving resistibility

	See/smell food	Months since surgery
Months since surgery	-0.16	
EDE-Q Overvaluation	-0.48**	0.35*

** p< 0.05 **p<0.01*