Psychometric and behavioural examination of the validity of “food addiction” in the general population

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The candidate confirms that the work submitted is his/her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

Chapter 2 of this thesis was based on the jointly-authored publication:

Long, C. G., Blundell, J. E., & Finlayson, G. (2015). A Systematic Review of the Application And Correlates of YFAS-Diagnosed ‘Food Addiction' in Humans: Are Eating-Related ‘Addictions' a Cause for Concern or Empty Concepts? *Obesity Facts*, 8(6), 386-401.

The candidate confirms that her contribution was primarily intellectual and she took a principal role in the production and writing of the publication. The co-authors confirm that their contribution was in guiding the research and reviewing drafts of the manuscript.

Parts of the methodology included in Chapter 6 have incorporated in the jointly-authored publication:

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The candidate confirms that the data collection was a collaborative process alongside the First Author, K. Beaulieu, and the candidate took an active role in this procedure. The results and analysis in Chapter 6 are exclusive to this thesis.

Chapter 7 of this thesis was a secondary analysis of the data collected for the publication:

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Though the candidate had no involvement in the original data collection for this study, the analysis and writing included in Chapter 7 is purely that of the candidate. The authors of the original publication gave explicit permission for the data to be analysed for this thesis.

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Abstract

Background

Some people attribute the failure to control their consumption of frequently consumed, often highly palatable foods to ‘Food Addiction’ (FA), but the scientific validity and utility of this term is disputed. In 2009, a tool was developed in an attempt to diagnose and measure the severity of so-called FA: the Yale Food Addiction Scale (YFAS), which has formed the cornerstone of the human experimental literature on FA. This thesis aims to examine the psychometric construct of FA and the YFAS through: a systematic literature review (Chapter 2); examining the psychometric properties of the YFAS using factor analysis (Chapter 3) and a comparison with a widely-used measure of trait binge eating (Chapter 4) and; exploring the role of YFAS scores on food perceptions (Chapter 5), and homeostatic (Chapter 6) and hedonic (Chapter 7) control of appetite.

Results

Much of the literature on FA made the assumption that food addiction is a valid diagnosable condition. However, this interpretation was based on very limited data (Chapter 2) and a tool with weak psychometric properties (Chapter 3) which was not able to distinguish behavioural characteristics from those identified by the Binge Eating Scale (BES; Chapter 4). High fat and energy dense foods were perceived as most associated with ‘problematic eating behaviours’ and ‘addictive potential’, though these perceptions were not related to YFAS scores (Chapter 5). Higher YFAS scores were associated with lower habitual physical activity, but no impairment to homeostatic control of food intake (Chapter 6), though high YFAS scorers demonstrated greater energy and fat intake, along with a preference for high fat sweet foods and snacks (Chapter 7).

Conclusion

It was concluded that FA appears synonymous with strong preferences towards highly palatable foods, especially high fat, sweet snacks. The work in the thesis found no strong evidence that food addiction (as measured by the YFAS) is associated with ‘addictive’ food behaviour or obesity. Research and debate surrounding the YFAS may divert attention and resources away from identifying and addressing the psychobiological determinants of overeating.

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Publications and Presented Work

Publications

Long, C. G., Blundell, J. E., & Finlayson, G. (2015). A Systematic Review of the Application And Correlates of YFAS-Diagnosed ‘Food Addiction' in Humans: Are Eating-Related ‘Addictions' a Cause for Concern or Empty Concepts? *Obesity Facts*, 8(6), 386-401.

Beaulieu, K., Hopkins, M., Long, C., Blundell, J., & Finlayson, G. (2017). High Habitual Physical Activity Improves Acute Energy Compensation in Nonobese Adults. *Medicine and science in sports and exercise*, 49(11), 2268-2275.

Presentations

Oral Presentations

Long, C., Finlayson, G., & Blundell, J. (2017). Is food addiction a singular and distinct entity from binge eating? Presented at *The European Congress on Obesity*, Porto, Portugal.

Poster Presentations

Long, C., Finlayson, G., & Blundell, J. (2016). An examination of the psychometric construct of ‘food addiction’ and its relationship with trait binge eating, addictive personality and psychological wellbeing. Presented at *The 40th Anniversary Meeting of the British Feeding and Drinking Group*, Teddington, London.

Long, C., Finlayson, G., & Blundell, J. (2016). An examination of the psychometric construct of ‘food addiction’ and its relationship with trait binge eating, addictive personality and psychological wellbeing. Presented at *The European Obesity Summit*, Gothenburg, Sweden.

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List of Abbreviations

ADHD	Attention Deficit Hyperactivity Disorder
AIC	Akaike Information Criterion
AMPM	Automated Multiple Pass Method
ANOVA	Analysis of Variance
APP	Addiction-Prone Personality Scale
AUDIT	Alcohol Use Disorder Identification Test
BDI	Beck Depression Inventory
BE	Binge Eating
BED	Binge Eating Disorder
BES	Binge Eating Scale
BF	Body Fat
BMI	Body Mass Index
BN	Bulimia Nervosa
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CHO	Carbohydrate
CoEQ	Control of Eating Questionnaire
DA	Dopamine
DAST	Drug Abuse Screening Test
DR	Dietary Recall
DSM	Diagnostic and Statistical Manual of Mental Disorders
EARS	Electronic Appetite Rating System
EB	Eating Behaviour
EC	Energy Compensation
ED	Energy Density
ED	Eating Disorder
EDE	Eating Disorder Examination
EE	Energy Expenditure
EEG	Electroencephalography
EI	Energy Intake
FA	Food Addiction
FFM	Fat Free Mass
FFQ	Food Frequency Questionnaire
FM	Fat Mass
fMRI	Functional Magnetic Resonance Imaging
GI	Glycaemic Index
HEP	High Energy Preload
HFA	High Food Addiction Group
HFSA	High Fat Savoury
HFSW	High Fat Sweet
HR	Heart Rate
IPAQ	International Physical Activity Questionnaire
KMO	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
LEP	Low Energy Preload
LFA	Low Food Addiction Group
LFPQ	Leeds Food Preference Questionnaire
LFSA	Low Fat Savoury
LFSW	Low Fat Sweet

LNBE	Low/Non-Binge Eater
MDD	Major Depressive Disorder
MFA	Moderate Food Addiction Group
MVPA	Moderate-to-Vigorous Physical Activity
NAcc	Nucleus Accumbens
NEP	No Energy Preload
OFC	Orbitofrontal Cortex
PA	Parallel Analysis
PA	Physical Activity
PAL	Physical Activity Level
PCA	Principal Components Analysis
PET	Positron Emission Tomography
PFS	Power of Food Scale
PSS	Perceived Stress Scale
PTSD	Post-Traumatic Stress Disorder
RMR	Resting Metabolic Rate
RMSEA	Root Mean Square Error of Approximation
RQ	Respiratory Quotient
SBE	Severe Binge Eater
SD	Standard Deviation
SNP	Single-Nucleotide Polymorphism
STAI	State-Trait Anxiety Index
SUD	Substance Use Disorder
SWA	SenseWear Armband
TFEQ	Three Factor Eating Questionnaire
TLI	Tucker Lewis Index
TM	Test Meal
TP	Time Point
VAS	Visual Analogue Scale
VIF	Variance Inflation Factor
WHO	World Health Organisation
WHOQOL	World Health Organisation Quality of Life Assessment
WLS	Weight Loss Surgery
YFAS	Yale Food Addiction Scale

Chapter 1

General Introduction

1.1 Background

Worldwide obesity has nearly doubled since 1980 according to the World Health Organisation (WHO; World Health Organisation, 2013). This has prompted large amounts of research and investment to target the prevention and treatment of obesity, but results tend to be unsatisfactory and most people regain any lost weight within five years (National Heart Lung and Blood Institute, 1998). In this context, the notion of ‘food addiction’ (FA) has been proposed (Davis & Carter, 2009; Gearhardt, Corbin, & Brownell, 2009b; Meule & Gearhardt, 2014a), suggesting that obesity may be driven by a dependence on food in a manner similar to dependence on drugs of abuse (Gearhardt, Corbin, & Brownell, 2009a; Taylor, Curtis, & Davis, 2010).

FA was first proposed in scientific literature more than 60 years ago, with the publication of Theron Randolph’s paper, titled “The descriptive features of food addiction; addictive eating and drinking” (Randolph, 1956), yet the term FA remains evident in everyday discourse. Individuals commonly refer to intense cravings and food preferences as an ‘addiction’; for example: “I’m totally addicted to [insert food here]”. However, in more recent years, driven in part by the rising prevalence of worldwide obesity, a new portrayal of food addiction as a clinical or neurobiological disease has emerged, attributing excessive food consumption with the neural and behavioural impairments commonly associated with clinically-defined substance-related and addictive disorders, as defined by the Diagnostic and Statistical Manual of Mental Disorders (DSM; American Psychiatric Association, 2000; American Psychiatric Association, 2013). This growing literature base not only states that some aspects of overeating and obesity may best be understood within an addiction framework (Volkow, Wang, Tomasi, & Baler, 2013), but advocates that some foods should be considered addictive substances, and that some individuals, especially those with obesity, should be considered as addicted to food (for example; Davis, Curtis, et al., 2011; Gearhardt, Davis, Kuschner, & Brownell, 2011; Hebebrand et al., 2014). Such literature asserts that FA is a unique behavioural phenotype, defined by characteristics which resemble the symptoms of drug addicts, and which predisposes certain individuals to develop ‘addictive’ behaviours towards certain foods.

One part of this trending belief can be attributed to the development of a questionnaire designed to ‘diagnose’ so-called food addiction in numerous populations: the Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009b). This tool has provided a focus for a growing body of literature which assumes that so-called FA is a valid and measurable condition. Despite the mounting interest in this perspective, some doubt and debate has emerged regarding the utility of FA as a concept, as well as the validity of the YFAS in measuring it (for example; Finlayson, 2017; Rogers, 2013; Ziauddeen & Fletcher, 2013). In an attempt to understand this debate, therefore, this introductory chapter will critically discuss the definition and assessment of FA, as well as the key propositions most frequently cited in support of FA: the behavioural similarities between overeating and drug abuse; neuroscientific overlaps between obesity and drug addiction in humans; and finally, animal models of overeating.

1.2 Defining addiction

Before discussions around the validity of FA can ensue, it is important that what is meant by ‘addiction’ is defined. The term ‘addiction’ comes from the Latin *addicere* meaning to assign or sentence (Waite, 2012), and was originally used to refer to any intense inclination towards an action, good or bad (Warburton, 1985). When maladaptive drug use was labelled an ‘addiction’ in the twentieth century (Warburton, 1992), the perspective on addiction shifted to imply a detrimental and often illegal pattern of substance consumption. More recently however, the common semantics of addiction seem to have returned to their classical origins, not limited to specific substances which promote physical dependence, but referring to behaviours, such as gambling and possibly food (Edwards, Arif, & Hadgson, 1981; Walters & Gilbert, 2000). Now, the term ‘addiction’ is applied in everyday discourse, referring to any behaviour deemed pleasurable or habitual, including television and shopping.

The case has been made to dispose of the term ‘addiction’ altogether, possibly replacing it with ‘dependence’, a term which appears to better represent dysfunctional or harmful substance misuse (Johns, 1990), as is the case in the fourth edition of the DSM (DSM-IV-TR; American Psychiatric Association, 2000). Yet this argument seems to have gone full circle, given the updated fifth edition (DSM-5) which re-titled the chapter ‘Substance Use and Addictive Disorders’, highlighting the continued relevance of this label in a clinical setting (Finlayson, 2017). Evidently, the term ‘addiction’ will continue to be used in everyday discourse and cannot be dispensed with completely (Rogers & Smit, 2000). Whilst specific scientific definitions of addiction continue to differ, most emphasise a transition from impulsivity towards compulsive or habit-driven consumption, a loss-of-control over use and distress associated with withdrawal (Akers, 1991; Everitt et al., 2008; Heather, 1998).

1.2.1 Proposed definition of food addiction

The definition of ‘food addiction’, however, is often less clear-cut, whether it is used in a scientific or lay sense. Currently no specific definition for FA exists, with the literature instead drawing parallels between overeating and substance use. The problems this ambiguity brings are represented in the use of the YFAS, which attempts to quantify the parallels between excessive food consumption and symptoms of substance dependence, as defined by the seven symptom criteria for substance dependence as outlined in the DSM-IV-TR (displayed in *Table 1*). The scale involves extrapolating the DSM criteria and replacing the word ‘substance’ with ‘food’, plus inclusion of an additional two items to assess clinical impairment or distress as a result of overeating (Gearhardt et al., 2009b). A dichotomous ‘diagnosis’ of FA is achieved if at least 3 of the 7 symptoms are endorsed, plus at least one marker of significant clinical distress. Alternatively, a ‘symptom count’ can be used to apply a score between 0 and 7 depending on the number of criteria endorsed, representing the severity of the proposed symptomatology. More recently, a continuous “sum-score” (Price, Higgs, & Lee, 2015, p. 206) of the 22 ‘active’ items has been adopted, applicable due to the one-factorial structure of the YFAS (Meule, Heckel, & Kübler, 2012), and allowing more direct comparisons to other eating behaviour scales.

Table 1. The DSM-IV-TR criteria for Substance Dependence (American Psychiatric Association, 2000)

1) Tolerance, as defined by either of the following:

   a. A need for markedly increased amounts of the substance to achieve intoxication or desired effect

   or

   b. Markedly diminished effect with continued use of the same amount of the substance

2) Withdrawal, as manifested by either of the following:

   a. The characteristic withdrawal syndrome for the substance

   or

   b. The same (or a closely related) substance is taken to relieve or avoid withdrawal symptoms

3) The substance is often taken in larger amounts or over a longer period than was intended

4) There is a persistent desire or unsuccessful efforts to cut down or control substance use

5) A great deal of time is spent on activities necessary to obtain the substance (e.g., visiting multiple doctors or driving long distances), use the substance (e.g., chain-smoking), or recover from its effects

6) Important social, occupational, or recreational activities are given up or reduced because of substance use

7) The substance use is continued despite knowledge of having a persistent physical or psychological problem that is likely to have been caused or exacerbated by the substance (e.g., current cocaine use despite recognition of cocaine-induced depression, or continued drinking despite recognition that an ulcer was made worse by alcohol consumption)

1.2.2 Psychometric assessment of ‘food addiction’

Despite the lack of a clinical definition, research investigating FA has persevered and the YFAS has begun to form the cornerstone of FA literature. This has given way to an exponential rise in research concerned with 'diagnosing' FA symptomatology based upon responses to the self-report YFAS (Gearhardt, Davis, et al., 2011; Meule, 2015). As a result, characterisation of a group of individuals who endorse the proposed symptoms of FA has ensued (for example; Brunault, Ballon, Gaillard, Reveillere, & Courtois, 2014; Gearhardt, Boswell, & White, 2014; Mason, Flint, Field, Austin, & Rich-Edwards, 2013). To date, the YFAS has identified a high prevalence of YFAS-defined food addiction in overweight and obese samples, as well as those with Binge Eating Disorder (BED). Furthermore, normal- and underweight individuals and even children have successfully met the YFAS criteria for FA. Interestingly, the use of the YFAS in scientific research has continued despite limited knowledge of its psychometric validity. For example, research conducting factor analyses of the YFAS have consistently revealed an underlying one-factor structure (for example; Brunault et al., 2014; Gearhardt et al., 2009b; Innamorati et al., 2015), which authors have interpreted to represent FA. This has led to the premature conclusion that the YFAS is a valid tool to measure FA symptomatology, an assumption which will be investigated further in Chapter 3. Indeed, much of the research to date is concerned with 'diagnosing' so-called FA in various samples, rather than investigating the utility of this proposed condition in advancing understanding of overeating.

Though the original YFAS remains prevalent in scientific literature at present, a recent revision to the scale, in line with the publication of the fifth edition of the DSM (DSM-V; American Psychiatric Association, 2013) has been issued. The YFAS 2.0 (Gearhardt, Corbin, & Brownell, 2016) now includes eleven, rather than seven, symptomatic criteria plus an additional diagnostic criterion of significant clinical distress. The YFAS 2.0 requires only two symptoms to be met, plus endorsement of the 'impairment or distress' criteria, in order for an individual to be given a 'diagnosis' of FA (compared to three symptoms in the original YFAS). A diagnosis is now represented on a continuum of severity, ranging from mild (2-3 criteria met) to severe (6 or more criteria met). If these updated criteria for the psychometric assessment of so-called food addiction are adopted, it is likely that the current prevalence estimates for the diagnosis of FA will no longer apply due to lower diagnostic thresholds (Meule & Gearhardt, 2014b). Therefore, results across the YFAS and YFAS 2.0 should be cautioned against in order to avoid over-diagnosis and misleading prevalence estimates. The first version of the YFAS, rather than the YFAS 2.0, will be used throughout this thesis, due to its use in over seven years' worth of research into FA, which, compared to the YFAS 2.0 published in 2016, will allow a more critical analysis of the assumptions surrounding FA.

Importantly, however, FA is not recognised as a valid clinical condition by the American Psychiatric Association. In the DSM-5, food addiction was considered for inclusion but rejected, although it was noted that some individuals in the newly defined ‘Feeding and Eating Disorders’ chapter may “report eating-related symptoms resembling those typically endorsed by individuals with substance use disorders, such as craving and patterns of compulsive use” (American Psychiatric Association, 2015; p.1). Binge Eating Disorder (BED), on the other hand, was recognised and included as a distinct condition in the ‘Feeding and Eating Disorders’ chapter, where previously it had only been included in the appendices of the DSM-IV. As the DSM is key to the classification of clinically-recognised conditions, providing agreed definitions and diagnostic procedures for healthcare professionals, the absence of FA from the DSM-5 should caution against the acceptance of food addiction as a valid and identifiable condition (Blundell, Coe, & Hooper, 2014; Finlayson, 2017). This lack of recognition can be attributed, in part, to the absence of a clear definition of FA, despite the proliferation of research utilising the YFAS. The criteria for substance dependence may not translate well to eating behaviours, a notion which will be discussed further in the next section, therefore a specific range of symptoms or behaviours which supposedly characterise FA appears to be lacking.

1.3 Proposed behavioural similarities between substance use and overeating

A key proposition cited in favour of FA concerns the observed behavioural similarities between overeating and substance-related disorders. As defined by the DSM-IV-TR, substance dependence is a “cluster of cognitive, behavioural and physiological symptoms associated with the continued use of the substance despite significant substance-related problems” (American Psychiatric Association, 2000). Whilst the DSM-5 retains this definition, it further sub-divides Substance-Related and Addictive Disorders into ‘Substance-Related’ and ‘Non Substance-Related Disorders’, reflecting the acknowledgment of behavioural disorders, such as gambling disorder, as clinical conditions. As the YFAS will be utilised throughout this thesis, the comparability of the DSM-IV-TR criteria (*Table 1*) with eating behaviour will be discussed here.

At face value, some of these criteria seem to translate well to commonly recognised overeating behaviours. For example, the “substance taken in larger amounts or over a longer period than was intended” criterion represents a common feature of overeating experienced by many people. In addition, the “persistent desire or unsuccessful efforts to cut down or control substance use” criteria may reflect the frequent, but often unsuccessful dieting strategies evident in individuals who find it difficult to manage their weight. Similarly, the “substance use is continued despite knowledge of having a persistent physical or psychological problems” criterion may be interpreted as reflecting the continued overeating despite weight gain evident in overweight or obese individuals. Therefore, when taken out of a clinical context, these criteria are rather ambiguous and can be made relevant to a large proportion of the general (especially overweight or obese) population.

Other behavioural criteria of substance dependence are less applicable to overeating. Namely, tolerance, defined as “decreased sensitivity to a drug that comes from its repeated use” (O'brien, 2011; Rogers & Smit, 2000, p.4), cannot be directly applied to food consumption, as food must repeatedly be consumed in order to maintain cellular energy. Similarly, evidence for withdrawal from food has not been conclusively demonstrated in humans (Pelchat, 2009; Ziauddeen, Farooqi, & Fletcher, 2012b). Whilst overweight or obese individuals might experience distress when engaging in a weight-loss attempt, such behaviours cannot be equated to the withdrawal effects seen when drug-dependent individuals are removed from their substance, features of which include dysphoria, nausea and insomnia (American Psychiatric Association, 2013). Perhaps individuals with obesity only exhibit some behavioural features of substance dependence if interpreted in a wider, non-clinical sense.

1.3.1 Suggested overlap between FA and binge eating behaviour

Further exploration of the classification of substance dependence appears to reveal that such criteria map more accurately onto the symptomatology for Binge Eating Disorder. BED is a recognised clinical condition, characterised by “recurrent episodes of binge eating”, accompanied by “marked distress”, in the absence of “inappropriate compensatory behaviours” (Grilo, 2002, p. 179). The existence of a clearly defined clinical syndrome for BED allows comparisons to easily be made with substance dependence. For example, the increasing frequency of bingeing episodes and amount of food consumed in each bingeing episode could be indicative of a tolerance effect (Gearhardt et al., 2009a).

Similarly, the DSM criteria for BED concerning “eating, in a discrete period of time, an amount of food that is definitely larger than most people would eat during a similar period of time and under similar circumstances” (American Psychiatric Association, 2015), appears to represent the “substance taken in larger amounts or over a longer period than was intended” criteria for substance dependence. In addition, the “great deal of time spent on activities necessary to obtain, use or recover from the substance” criterion appears to reflect features of BED whereby binge eating occurs, on average, at least 1 day a week for 3 months (American Psychiatric Association, 2013). Finally, the “important social, occupational, or recreational activities are given up or reduced because of substance use” criterion may reflect the “eating alone because of feeling embarrassed by how much one is eating” feature of BED. Such arguments may suggest that the binge eating model may better fit the behaviours which are thought to be indicative of FA according to the YFAS.

On the other hand, some researchers have taken to the idea that FA may represent an ‘acute’ version of BED, signifying the extreme end on a continuum of overeating (Cassin & von Ranson, 2007; Davis, 2013a), a perspective possibly adopted as a result of the lack of clearly defined characteristics of FA. This perspective encompasses the features of loss of control over eating commonly observed in obesity, along with the compulsive aspects of BED. However, there are empirical arguments against considering food addiction as an acute version of binge eating disorder. Firstly, the strong similarities between FA and BED raise the possibility that the label of FA is redundant as the overlaps between overeating and substance use can already be characterised as BED. In addition, it has been reported (e.g., Davis et al., 2011) that not all individuals with BED meet the YFAS criteria for FA and not all individuals meeting a FA ‘diagnosis’ demonstrate BED behaviours. If FA is an ‘acute’ version of BED then it would be assumed that all individuals meeting the YFAS criteria for FA should also endorse a BED diagnosis. If FA is a distinct condition from BED then there needs to be evidence to demonstrate this, a proposition which will be examined further in Chapter 4.

1.4 Neuroscientific evidence cited in support of FA

Beyond phenotypic overlap between substance dependence and overeating, similarities in brain circuitry activated by food and drugs have been cited in favour of the existence of food addiction. Sustained drug taking is understood to lead to neural adaptations which produce an enhanced salience of drug-related cues and lead to compulsive drug seeking (Everitt et al., 2008; Vanderschuren & Everitt, 2004; Ziauddeen & Fletcher, 2013). Although there are numerous brain regions and neurotransmitters which are implicated in the reinforcing effect of drugs, particular attention has been given to those which show overlaps with the consumption of food, specifically dopamine (DA) and opioidergic transmission and receptor expression, particularly in the nucleus accumbens (NAcc) and striatum. The overlap in activity of these neurotransmitters caused by food and drugs will be discussed here.

1.4.1 Dopamine

It is widely reported that acute drug administration leads to repeated release of extracellular dopamine in the nucleus accumbens (Di Chiara & Imperato, 1988; Hernandez & Hoebel, 1988; Wise et al., 1995). On the contrary, with food consumption, these DA responses become blunted after repeated exposure as the stimulus loses its novelty (Bassareo & Di Chiara, 1997; Rada, Avena, & Hoebel, 2005) and satiation develops. It has been reported that in rats who are intermittently fed a high sucrose diet, DA release occurs every time the high sucrose diet is administered (Rada et al., 2005), suggesting that when highly palatable foods are present, neural responses similar to those observed in response to drugs are evident (Avena, Rada, & Hoebel, 2008). However, this highly constrained alternating access/restriction feeding regime has limited relevance to human eating behaviour.

After prolonged drug administration, changes in the availability and expression of dopaminergic receptors appear as a result of sustained DA release. Studies have revealed a role for dopamine D1, D2 and D3 receptors in the reinforcing effects of drugs. For example, the development of addiction to drugs has been associated with increased D1 receptor binding in the NAcc (Alburges, Narang, & Wamsley, 1993; Unterwald, Kreek, & Cuntapay, 2001) and similar effects have been demonstrated in rats fed an intermittent high sugar diet (Colantuoni et al., 2001). In addition, D3 receptor messenger RNA levels in the NAcc and striatum are increased following morphine (Spangler et al., 2004) and cocaine administration (Le Foll, Francès, Diaz, Schwartz, & Sokoloff, 2002), whilst a D3 receptor antagonist inhibits cocaine seeking (Vorel et al., 2002). Similar findings have been reported in human studies. For example, Segal, Moraes, and Mash (1997) demonstrated an increase in D3 receptor mRNA expression in the NAcc in post-mortem autopsies of chronic cocaine addicts compared to drug-free controls. Similarly, Mash and Staley (1999) reported cocaine abuse victims to have a one- to threefold increase in D3 binding sites in the NAcc compared to controls. However, these responses have not been replicated in humans in response to feeding.

Most notable of DA receptor adaptations is the observed decrease in D2 receptor binding in the striatum and NAcc with sustained drug use (Volkow et al., 2003). For example, in monkeys with a history of cocaine administration, D2 receptor density in the NAcc is reduced (Moore, Vinsant, Nader, Porrino, & Friedman, 1998). Similarly, in humans, D2 receptors have been reported to be down-regulated in cocaine addicts (Volkow et al., 2003; Volkow et al., 1993).

Further literature supporting the proposed associations in DA response between substance dependence and obesity come from genetic studies. Polymorphisms of the Taq1A minor (A1) allele of the dopamine receptor D2 gene have been suggested to be implicated in individuals with both substance dependence and obesity (Noble et al., 1993; Stice, Spoor, Bohon, & Small, 2008; Zuo et al., 2009), possibly via mechanisms on D2 receptor expression (Baik, 2013). A significant body of evidence supports the proposition that individuals with a Taq1A polymorphism have compromised DA expression, possibly as a result of D2 receptor density decreases (Jönsson et al., 1999). These findings support a possible genetic vulnerability towards DA receptor dysfunctions, though this evidence is not always replicated (for example, Southon et al., 2003). The A1 allele has also been found to have links with other disorders such as gambling (M. X. Cohen, Young, Baek, Kessler, & Ranganath, 2005), and is reported to be prevalent in 30-50% of non-clinical populations (M. X. Cohen et al., 2005; Noble, 2000). Though this suggests that a large number of individuals may be at risk of the D2 receptor expression, if the prevalence of the A1 allele is as high as suggested, much greater proportions of substance-related or behavioural impairments would be evident.

With regards to food intake, rats with intermittent access to sucrose and chow have presented decreased D2 receptor binding in the NAcc (Bello, Lucas, & Hajnal, 2002) and striatum (Colantuoni et al., 2001) in some studies, as well as decreased D2 receptor mRNA molecules (Spangler et al., 2004). In humans, a landmark study by Wang et al. (2001) used positron emission tomography (PET) scanning to reveal that obese participants had lower levels of striatal DA

D2 receptor availability compared to normal weight controls. Similar results have since been reported by Volkow, Wang, Telang, et al. (2008) and de Weijer et al. (2011), though in the latter study obese participants were scanned when fasted yet controls were analysed when satiated. However, further research has failed to replicate these findings, only revealing a statistically significant decrease in D2 receptor availability when using voxel-based analysis, rather than region of interest analysis (Haltia et al., 2007). Taken together, PET studies have been inconclusive in determining the role of DA D2 receptors in human obesity (Ziauddeen et al., 2012b). Furthermore, it remains unclear whether this DA dysfunction is a cause or consequence of increasing BMI (Pelchat, 2009).

Finally, neuroimaging studies have reported activation in the anterior insula and right orbitofrontal cortex (OFC) regions involved in the DA system following viewing picture stimuli of palatable foods (O'Doherty, Deichmann, Critchley, & Dolan, 2002; Wang, Volkow, Thanos, & Fowler, 2004). Activation in these regions has been found to be enhanced in obese subjects compared to lean individuals (Wang et al., 2002). Similarly, drug addicts have been demonstrated to exhibit greater activation in comparable brain regions when presented with drug-related cues (Due, Huettel, Hall, & Rubin, 2002; Maas et al., 1998). However, this response extends beyond behaviours or substances suggested to be ‘addictive’. For example, activation in the OFC is found in response to listening to music (Blood & Zatorre, 2001; Menon & Levitin, 2005). It is unlikely, therefore, that mesolimbic responses are solely indicative of an ‘addiction’ to a particular pleasurable stimulus.

Taken together, whilst these results highlight the common abilities of drugs and feeding in activating the mesolimbic regions of the brain when administered in highly contrived environments (Volkow, Fowler, & Wang, 2004; Volkow, Wang, Fowler, & Telang, 2008), it is a stretch to assume that this alone can suffice evidence for food addiction. It is unsurprising that cues of highly palatable foods result in increased activation of reward-related brain areas comparable to those involved in drug taking (Gearhardt & Corbin, 2011; O'Doherty et al., 2002), given the subjective pleasure derived from drugs and food.

1.4.2 Opioids

Drugs of abuse are also able to alter opioid receptors in mesolimbic brain regions. For example, mu-opioid receptor binding increases in response to escalating cocaine bingeing (Bailey, Gianotti, Ho, & Kreek, 2005; Unterwald et al., 2001) and morphine sensitisation (Vigano et al., 2003) in rats, whilst similar results have been reported in human studies. For example, Zubieta et al. (1996) used PET to reveal that mu-opioid binding in cocaine addicts was significantly increased compared to non-addicted controls, and this binding was correlated with the degree of cocaine craving at the time of measurement. Similarly, mu-opioid receptors were increased in hospitalised alcohol dependent males, even after 5-weeks of abstinence, and this increase in receptors correlated with the severity of alcohol craving (Heinz et al., 2005).

With regards to food intake, rats maintained on an intermittent access, high sucrose diet displayed significantly enhanced mu-opioid receptor binding (Colantuoni et al., 2001) in numerous brain regions. Similarly, administration of a mu-opioid receptor agonist enhances intake of fat or carbohydrates in rats (Zhang, Gosnell, & Kelley, 1998). Additionally, within this experimental paradigm, administration of the opioid antagonist naloxone presents features indicative of withdrawal in rats, such as teeth chattering and head shakes (Colantuoni et al., 2001).

In humans, the mu-opioid system has been suggested to play a role in mediating the palatability, or ‘liking’ of rewards (Berridge, 2009). Primary evidence for this comes from research demonstrating that administration of opioid receptor antagonists reduces subjective ratings of palatability (Fantino, Hosotte, & Apfelbaum, 1986) and decreases preference for palatable (to a greater extent than non-palatable) foods (Drewnowski, Krahn, Demitrack, Nairn, & Gosnell, 1992). Furthermore, administration of opioid antagonists decreases consumption of palatable foods even when satiated. For example, Yeomans, Wright, Macleod, and Critchley (1990) found that males administered the opioid antagonist nalmefene ate 22% less food in an *ad libitum* buffet compared to a control group, and fat intake was particularly reduced, suggesting a role of opioids in palatability-related food intake.

From a genetic perspective, the mu-opioid receptor (OPRM1) gene has received particular attention due to its role in drug dependence. In particular, the role of the “gain-of-function” A118G single-nucleotide polymorphism (SNP) of OPRM1 has been suggested to be implicated in individuals with both substance dependence and obesity. For example, OPRM1 polymorphisms have been reported to increase the risk of alcohol dependence (B. Gavin et al., 2005; Van Den Wildenberg et al., 2007) and heroin addiction (Bart et al., 2004). In light of this, a study by Davis et al. (2009) examined the expression of the OPRM1 gene in relation to overeating and obesity. In a sample of obese adults with or without BED, genotyping analysis revealed that a larger proportion of subjects with BED carried the A118G allele compared to those without BED. Such findings appear to suggest that a small subgroup of obese individuals with BED may possess a vulnerability towards addiction-related behaviours, defined by an increased responsiveness to palatable foods and substance addiction (Davis, Zai, et al., 2011).

1.4.3 Critique of the proposed neurological evidence for FA

All of this evidence considered, however, it is unsurprising that food and drugs produce comparable neural activity in mutual systems. These systems are understood to have evolved in humans to ensure that natural rewards, particularly food, were acquired for survival. It has been suggested that drugs ‘hijack’ the reward systems developed for natural rewards, not the converse (Blundell et al., 2014; Ziauddeen et al., 2012b). Whilst food and drugs may share common neurological action, these associations do not imply that their effects are equal, particularly as their neurological effects are not identical. Westwater, Fletcher, and Ziauddeen (2016) argue that there are distinct differences between food and drug consumption. For example, few NAcc neurons display overlapping activation in response to cocaine and food goal-directed behaviour (Carelli & Wondolowski, 2003). In addition, and as previously discussed, repeated administration of drugs such as cocaine retains its novelty, with a spike in activation after each administration, whilst the DA release in response to palatable food such as sugar plateaus as the food loses its novelty (Bassareo & Di Chiara, 1997; Rada et al., 2005). In addition, consumption of drugs of abuse produce an increase in dopamine release up to 10 times greater than that following natural rewards, such as food (Di Chiara et al., 1997). This difference in magnitude of DA response highlights that the proposed common neurobiology of food and drug consumption may not be as similar as appears at face value.

1.5 Possible evidence from animal models of FA

By far the most controversial evidence in favour of a possible addictive response to overeating comes from animal feeding studies. Using highly constrained dietary manipulations, behaviours supposedly resembling addictive symptoms have been reported in rodents. Landmark studies by Bart Hoebel and Nicole Avena have driven research in this area, and their findings have been loosely extrapolated to form arguments and conclusions about the existence of FA. For example, in a feeding regime developed by Avena et al. (2008), rats are deprived of food for 12-hours, then given 12-hours of access to a sucrose solution and chow. Using this dietary manipulation, Colantuoni et al. (2001) demonstrated that rats excessively consumed the sugar solution in the first hour of access and doubled their intake across 10-days of exposure to this diet. Comparable results were reported by Avena, Rada, Moise, and Hoebel (2006). This escalation of intake is reported to be suggestive of bingeing, a characteristic feature of drug abuse. Of interest, however, such studies reported that the rats reduced their usual chow consumption to control caloric intake, compensating for the energy consumed from the sugar solution and therefore regulating body weight (Avena & Hoebel, 2003; Colantuoni et al., 2002). This limits the applicability of these bingeing behaviours in the development of obesity, though such results may have implications for BED or bulimia nervosa (Hagan & Moss, 1997).

Alternative feeding regimes include ‘cafeteria’ style diets, in which rodents are given *ad libitum* access to highly palatable, energy dense foods such as chocolate, bacon and icing (P. M. Johnson & Kenny, 2010). Such feeding practices have provided insight into the control of body weight as rodents exposed to these diets are found to rapidly gain weight (Rolls, Rowe, & Turner, 1980). For example, P. M. Johnson and Kenny (2010) reported caloric intake in rats presented with an *ad libitum* cafeteria style-diet was almost twice as much as those with restricted access, and around 95% of this energy was consumed from the cafeteria diet rather than from their usual chow. Furthermore, following withdrawal from this cafeteria style diet, those animals who previously had been given *ad libitum* access endured an aversive environment (such as foot shock) in order to maintain consumption. In contrast, those rats that had been given restricted access avoided the aversive environment and consequently decreased intake of the cafeteria diet. Such results were interpreted by authors to indicate the development of ‘compulsive-like’ eating behaviour in response to highly palatable foods, and was compared to the compulsive nature of cocaine administration seen in rats with extended access to this drug (Vanderschuren & Everitt, 2004). These behaviours have been further compared to characteristics of obesity, such as the continuation of overeating despite known health consequences (P. M. Johnson & Kenny, 2010). It is a particularly large stretch of inference to attempt to compare the immediate consequences displayed by rats in heavily constrained environments and the long-term health consequences of sustained overeating in humans.

On the contrary, it can be argued that humans' eating behaviours may not be strongly influenced by their long-term health concerns. This is demonstrated by the high prevalence of weight regain following dietary and behavioural interventions (National Heart Lung and Blood Institute, 1998). Further research has shown that long-term body satisfaction does not serve to motivate healthy eating behaviours, but may instead encourage unhealthy diet practices, such as bingeing, smoking and lower levels of physical activity, in the short term (Neumark-Sztainer, et al., 2006). In light of this, perhaps the acute behaviours of animals are of more relevance to humans behaviour than thought at first instance. However, the presence of scientifically-modified, purpose-built food environments in these studies still limits the applicability of animal feeding models to humans.

However, the neurological changes reported to complement consumption of cafeteria style diets occur in opposing manners to restricted feeding regimes. For example, when rats are given *ad libitum* access to high sugar foods, the DA release plateaus as the food loses its novelty, eventually resulting in a blunted DA response. This is in contrast to drugs which stimulate DA release each time they are administered (Avena et al., 2008). Therefore, these highly palatable *ad libitum* feeding styles may be of more relevance to the development of obesity, yet are less akin to the behavioural and neurological adaptations associated with drug abuse.

Though the animal evidence reviewed above demonstrates some similarities between overeating and addiction, the conclusions which can be drawn from such studies are limited to suggesting that similar neuronal systems are implicated in the seeking and consumption of palatable food and drugs (at least in part). The reliance of such studies on highly constrained dietary restrictions and feeding patterns, such as 12-hour intermittent food restriction/access cycles, may not be applicable to the complex behaviour of human eating (Blundell et al., 2014; Rogers, 2013). Although ‘cafeteria style’ feeding regimes seem to be of more relevance to the human diet – given the abundance of widely available highly palatable foods in the modern environment – attempts to replicate these behavioural findings in humans have been unsuccessful to date (Benton, 2010; Ziauddeen & Fletcher, 2013). Given these methodological caveats, the relevance of this evidence to human behaviour must be interpreted cautiously. The use of animal models cannot be used to prove or disprove food addiction in humans, particularly as no animal model can totally encompass the highly complex wealth of factors involved in human eating behaviour (Corwin & Babbs, 2012; Corwin & Buda-Levin, 2004).

1.6 Are certain foods or food constituents addictive?

Certain foods, suggested to be capable of producing an ‘addictive response’ in humans (Avena, Bocarsly, Hoebel, & Gold, 2011; Cocores & Gold, 2009; Gearhardt, Davis, et al., 2011; Ifland et al., 2009; Volkow & Wise, 2005), have been labelled “addictive agents” (Schulte, Avena, & Gearhardt, 2015) and most commonly refer to refined carbohydrates, fat and salt, often in combination (Avena, Bocarsly, & Hoebel, 2012; Cocores & Gold, 2009; Gearhardt, Davis, et al., 2011). However, these claims that certain substances possess a degree of ‘addictive potential’ has stimulated significant debate (Corwin & Hayes, 2014; Finlayson, 2017; Rogers & Smit, 2000; Ziauddeen, Farooqi, & Fletcher, 2012a), an argument which will be discussed in detail in Chapter 5.

As has been discussed in this introductory chapter, highly palatable, high sugar and fat diets are often utilised in experiments to quantify suggested ‘addictive responses’ in humans and animals. However, evidence to support any specific addictive features of these ingredients is controversial at present (Corwin & Hayes, 2014). For example, the link between the consumption of foods such as carbohydrates and mood regulation is weak and requires unnatural consumption of large quantities of carbohydrates in isolation. Though attempts have been made to study this empirically, it has long been understood that the body is capable of producing sufficient carbohydrates through gluconeogenesis (Berg, Tymoczko, & Stryer, 2002; Pozefsky, Tancredi, Moxley, Dupre, & Tobin, 1976), therefore removing the biological requirement for the central nervous system to both crave or need carbohydrates, even in a state of starvation. Studies which have therefore suggested that consumption of high glycaemic index (GI) carbohydrates may foster specific cycles of overeating (Lennerz et al., 2013), or that the drive to consume high carbohydrate foods is an essential function for survival, (Macdonald, Francis, Gowland, Hardman, & Halford, 2013) seem to be overstated as reward-sensitive brain regions do not need repeated activation to ensure ongoing consumption (Blundell et al., 2014). In addition, in modern society, highly palatable foods contain varying proportions of carbohydrates and fat are often eaten preferably over other foods, therefore a preference for carbohydrate-rich foods does not suffice evidence for carbohydrate addiction, but simply demonstrates that highly palatable foods are strongly reinforcing (Hammersley & Reid, 1997).

The proposed mood-enhancing properties of carbohydrates do not make a strong case for their addictive properties, given that food consumption is generally pleasurable. Instead, an understanding of the mechanisms by which this reinforcement may occur and reach a uncontrollable degree is required (Rogers & Smit, 2000). In this way, chocolate has been proposed as a possible candidate for addiction because of the proposed psychoactive components of cocoa. For example, di Tomaso, Beltramo, and Piomelli (1996) identified the presence of anandamide, a fatty acid neurotransmitter which targets cannabinoid receptors in the brain (Pertwee, 2008), in chocolate and cocoa powder, though not in white chocolate or coffee. However, extremely low concentrations of anandamide were detected, such that, according to Rogers and Smit (2000), “a 70-kg person would need to eat about 25 kg of chocolate” (p.5) to achieve any noticeable psychoactive effects.

Indeed, a vast array of foods in the modern diet have been considered as candidates for promoting ‘addictive’ eating behaviours, including dietary staples such as bread, pasta and rice (Gearhardt et al., 2009b), and even carrots (Kaplan, 1996). Whilst high carbohydrate foods often feature in overeating or binge eating behaviour (Fullerton, Getto, Swift, & Carlson, 1985), many diets centre around these staple foods, thus an inability to cut-down on their consumption can hardly be considered an ‘addiction’ (Rogers, 2017). That notwithstanding, many individuals continue to consider themselves ‘addicted’ to particular foods, but whether this attribution should be taken as evidence that such foods can be addictive is debateable.

As a whole, the case for identifying an addictive ingredient in food is certainly hampered by the methodologies adopted in investigating so-called FA. Previous research has relied heavily on questionnaire-based and self-report methods of food intake and eating behaviour which is prone to mis- or under-reporting (R. Hill & Davies, 2001; Moshfegh et al., 2008). This limitation of research associated with FA will be addressed in Chapter 6 and Chapter 7, which present objectively-controlled laboratory-based and free-living studies of food intake and eating behaviours across female participants varying in score on the YFAS.

1.7 Objectives of the present thesis

The growing body of uncritical scientific literature, which makes the assumption that so-called food addiction is a true condition, may hinder progress in identifying preventable causes of overeating. The designation of any new putative mental disorder should not be taken lightly but should contribute novel information to the field which assists in explaining or treating a pathology and should not overlap extensively with existing validated explanations or disorders. In response to this, objective scientific research is required to investigate the utility of the concept of "food addiction" in the scientific literature before it is accepted by the scientific population and communicated to the public.

The objective of this thesis, therefore, is to investigate the construct of food addiction through its proposed diagnostic tool: the YFAS. The YFAS will be used throughout this thesis to allow for the identification of any psychological, behavioural or physiological characteristics which distinguish those individuals who score high on the YFAS from those with low scores. The specific objectives that will be addressed in this thesis are:

1. To critically examine the assumptions around FA by reviewing the literature employing the Yale Food Addiction Scale and related constructs (e.g. eating addiction) in the general population and relevant subgroups **(Chapter 2)**
2. To examine the psychometric properties of the YFAS and assess its validity as an instrument to measure and diagnose 'food addiction' **(Chapter 3)**
3. To examine whether alleged FA, as defined by the YFAS, is distinct from existing eating behaviour phenomena (especially binge eating) in the general population and its association with significant physical or psychological distress or addictive personality characteristics **(Chapter 4)**
4. To identify which food attributes are most strongly associated with perceptions of 'addictive' potential or problematic eating behaviours, and whether such perceptions differ across YFAS-defined 'food addicts' and 'non-food addicts' **(Chapter 5)**
5. To investigate whether individuals with high scores on the YFAS respond differently to a challenge to homeostatic appetite control **(Chapter 6)**
6. To examine the ways in which the YFAS is related to food preferences, food reward (liking and wanting) and experiences of food cravings in a laboratory and free-living setting **(Chapter 7)**

7. To discuss the implications and interpretation of the findings outlined in this thesis for the concept of ‘food addiction’ and the value of its proposed diagnostic tool, the YFAS. **(Chapter 8)**

Chapter 2

A systematic review of the application and correlates of YFAS "food addiction" in humans: are eating-related addictions a cause for concern or an empty concept?

Aims

- To systematically review the literature on "food addiction", as measured by the Yale Food Addiction Scale
- Critically evaluate the prevalence of FA in multiple groups, including obese and overweight individuals, patients with binge eating disorder and bulimia nervosa, children and the general population
- Examine the correlates of food addiction, including, but not limited to, psychological distress, weight loss outcomes and susceptibility to maladaptive eating behaviours
- Evaluate the utility of the Yale Food Addiction Scale and its application of the DSM-IV criteria for substance dependence in identifying dysfunctional patterns of eating

2.1 Abstract

Background: The proposition of so-called “food addiction” (FA) in the scientific literature has stimulated a recent surge in research and debate. The concept of FA is controversial and opinion is divided. Many of the findings depend upon the use of a single instrument called the Yale Food Addiction Scale (YFAS).

Method: This chapter systematically reviewed the prevalence and correlates of “food addiction”, as defined by the Yale Food Addiction Scale, reported in forty experimental human studies published between 2009 and November 2015.

Results: The results indicated that much of the literature makes the supposition that food addiction is an accepted neurobiological disease, consistent with substance-use disorders; an interpretation based on very limited data. This raises the question as to whether those individuals who meet the YFAS criteria for FA are truly ‘addicted’ to food, an idea which could be plausible if they experience significant impairment to their psychological wellbeing and quality of life as would be expected in clinically recognised addictive disorders. At the present time, little research has objectively investigated the extent to which a psychometric self-assessment of FA symptomatology can elucidate a harmful relationship with target foods in the diet. A positive YFAS diagnosis is usually positively associated with BMI and strongly linked with the presence of binge eating, but certain exceptions within the literature were revealed.

Conclusions: Further clarification is required as to whether so-called food addiction is sufficiently different from existing validated models of overeating to warrant classification as a distinctive disease phenotype, rather than an expression of strong habits and preferences.

2.2 Introduction

The idea that certain foods and beverages may have “addictive potential” is not new (Gold, Frost-Pineda, & Jacobs, 2003), yet an exponential growth in research around this proposed concept of ‘Food Addiction’ in recent years (Gearhardt, Davis, et al., 2011) has led to contradictory positions regarding the existence of FA as a putative neurological condition, consistent with substance dependence and addictive behaviour disorders, as diagnosed by the Diagnostic and Statistical Manual (DSM; American Psychiatric Association, 2000).

Despite this increasing research base, FA – its definition, aetiology, validity and value – is still not clear, nor fully understood. Moreover, arguments promoting the existence of FA as a valid condition are exacerbated by a lack of balanced scientific discussion and methodology. In part, this feature of the literature can be explained by the development and popularity of the Yale Food Addiction Scale (YFAS), designed to quantify hypothesised symptoms of “food addiction” as described in detail in Chapter 1. The psychometric properties of the YFAS have been reported as being reliable (e.g., Gearhardt et al., 2009b), and whilst this will be further investigated in Chapter 3, the use of this metric does not validate the construct of “food addiction”, but merely assigns to people a score based on their responses to certain questions. Furthermore, the interpretation of correlations between YFAS scores and various measures of problematic eating behaviour, psychological impairment and anthropometrics has led to the premature conclusion that these traits define a so-called “food addiction phenotype”. However, it is often overlooked that the interpretation of self-report responses is not a simple matter and cannot automatically be assumed to reveal an underlying pathology or psychological condition.

In light of this, a systematic review of the literature surrounding the concept of “food addiction”, as measured by the YFAS, is warranted, in order to explore the specific applications and correlates of so-called FA, as well as to identify areas to balance discussion and methodology. At the time of writing, no systematic research review has been conducted to critically examine both the prevalence and correlates of food addiction as measured by the YFAS. Numerous studies have investigated specific correlates of FA, including measures of psychological distress, such as depression (Burmeister, Hinman, Koball, Hoffmann, & Carels, 2013) and attention deficit hyperactivity disorder (ADHD; Davis, Curtis, et al., 2011), pathological eating behaviours, including

Binge Eating Disorder (Gearhardt, White, et al., 2012) and Bulimia Nervosa (BN; Meule, von Rezori, & Blechert, 2014) and weight loss outcomes (Pepino, Stein, Eagon, & Klein, 2014). Further, a recent publication by Pursey, Stanwell, Gearhardt, Collins, and Burrows (2014) reviewed the prevalence of FA as defined by the YFAS in twenty-five studies published before July 2014. Nevertheless, no review has been conducted to summarise and critically examine both the prevalence and correlates of the YFAS in different populations.

2.2.1 Objectives

Specifically, the objectives of the present systematic review are threefold:

1) To explore the prevalence of YFAS-defined FA in multiple groups, including obese and overweight individuals, patients with binge eating disorder and bulimia nervosa, children and the general population
2) To examine the correlates of YFAS-defined FA, including, but not limited to, psychological distress, weight loss outcomes and susceptibility to maladaptive eating behaviours
3) To evaluate the utility of the YFAS and its application of the DSM-IV-TR criteria for substance dependence in identifying a novel behavioural phenotype of overeating, diagnostically and behaviourally different to existing eating disorder phenotypes.

2.3 Methods

A systematic review of the literature relating to YFAS determined food addiction was performed in November 2015. Titles, abstracts and full texts were screened to assess their eligibility for inclusion using the following search strategy.

2.3.1 Key terms and limits

Literature searches were carried out using the key terms ‘food addiction’, ‘food addict*’, ‘Yale Food Addiction Scale’, ‘YFAS’ or ‘eating addict’. The search results were limited to humans and the English language. As the Yale Food Addiction Scale was developed in 2009, literature published before this date was not considered.

2.3.2 Databases

The search strategy was conducted using the databases Embase, PsycINFO, MEDLINE, Science Direct and Web of Science. Hand searching of citations in review articles provided were performed to identify any additional sources.

2.3.3 Inclusion and exclusion criteria

No exclusion criteria were applied to sample demographics. Male and female participants of all ages, including children, were included, as were normal weight, overweight and obese samples. Only experimental studies measuring the prevalence or correlates of YFAS determined food addiction were included. As such, all review papers (N=23), case studies (N=1), validation studies (N=7) or non-experimental uses of the YFAS (N=24) were excluded. Only peer-reviewed articles were included, thus dissertation and thesis papers (N=3), conference abstracts (N=22) and books (N=8) were excluded.

2.3.4 Data extraction

332 studies were initially identified using the predefined search strategy. A flowchart outlining the data extraction method is presented in *Figure 1*. After applying the exclusion criteria and removing duplicates, forty relevant studies met the predefined criteria for inclusion in this systematic review. Studies most commonly excluded were those which analysed or reviewed the validity and

reliability of the YFAS or similar eating behaviour scales without reporting the prevalence or correlates of “food addiction”. Results were summarised according to two main categories: Prevalence and Correlates, and a summary of results is included in Appendix A.

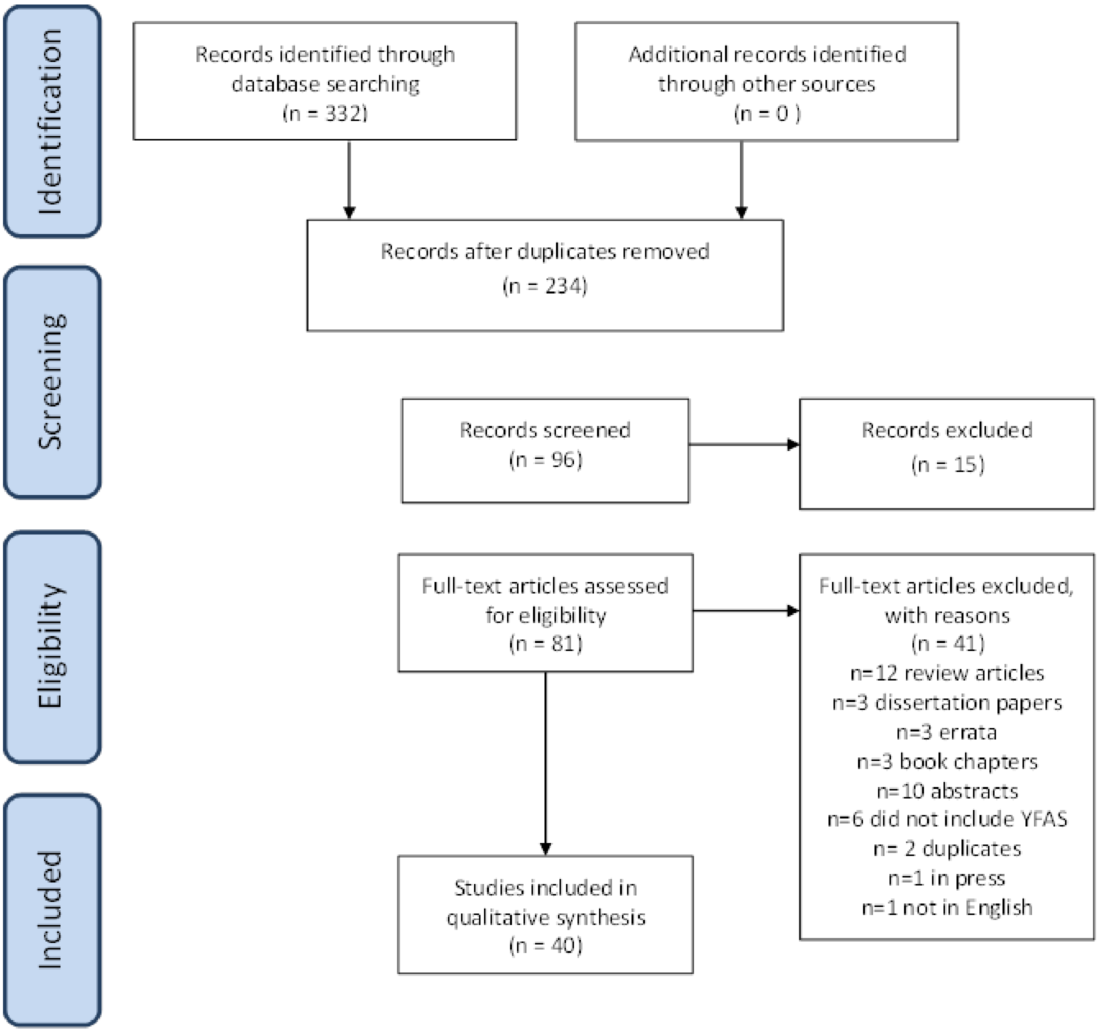

Figure 1. PRISMA Flowchart depicting the search strategy

19 of the included studies recruited samples of obese or overweight individuals. Of these studies, 12 investigated the associations between YFAS diagnosis and weight loss treatment or surgery, including the prevalence of a YFAS endorsement before and after treatment (N=4), weight loss outcomes (N=5), remission of YFAS diagnosis following weight loss surgery (N=1) and associations between YFAS diagnoses pre-surgery and substance or alcohol misuse post-surgery (N=3). Two studies recruited individuals with BED. In both of these studies the participants were also overweight or obese and in one of these investigations the sample was also seeking weight loss treatment.

Eighteen studies investigated the prevalence and correlates of food addiction in the general population. Ten studies focused on female samples only, however no studies recruited solely male participants, thus the remaining studies recruited both males and females (N=30). One study used a sample of children whilst two studies selectively recruited samples with eating disorders. The total number of participants across all included studies was 248,474, with sample sizes ranging from 27 to 57,321. Twenty-one studies were published after 2013, whilst only one was published before 2010.

2.4 Results

2.4.1 Prevalence of food addiction

Thirty-six studies reported the prevalence of YFAS-defined FA in their respective samples. Seven studies reported the YFAS symptom count only, fourteen reported the percentage of the sample meeting a dichotomous YFAS diagnosis and a further fourteen reported both. The remaining study did not adhere to the standardised scoring criteria for the YFAS (Karlsson et al., 2015). Of these investigations, 19 reported the prevalence of a YFAS diagnosis in overweight or obese samples, 19 in the general population, one in children and two in samples with eating disorders; one of which specified bulimia nervosa (BN) only and the other included a sample with various ED subtypes. Evidently, the YFAS is identifying individuals across numerous clinical and non-clinical samples who identify as “food addicts”, according to their responses on the YFAS. The prevalence of YFAS diagnosis within these clinical and non-clinical populations will be discussed further.

2.4.1.1 Overweight and obese samples

The prevalence of reported YFAS “diagnoses” of FA was consistently greater in overweight and obese samples, relative to normal or underweight individuals. Specifically, the prevalence of a dichotomous YFAS “diagnosis” in overweight or obese individuals ranged from 15.2% (Eichen, Lent, Goldbacher, & Foster, 2013) to 56.8% (Gearhardt, White, et al., 2012), whilst the mean YFAS symptom count reported in these samples ranged from 2.57 (Eichen et al., 2013) to 4.56 (Gearhardt, White, et al., 2012) out of a possible seven. A comparison of the median prevalence in the overweight or obese samples (33%) and general population (6.8%) reflects a 4 to 5 times greater YFAS prevalence in overweight and obese samples. This value exceeds previous findings by Avena, Gearhardt, Gold, Wang, and Potenza (2012) who reported a two- to three-fold increase in YFAS diagnosis in obese individuals compared to normal weight samples, and the results of a meta-analysis by Pursey, Stanwell, Gearhardt, et al. (2014), who reported that the prevalence of FA was double in the overweight/obese population compared with healthy weight individuals. The highest prevalence rates were reported in weight loss surgery-seeking overweight and obese patients, in whom prevalence rates reached 53.7% (Clark & Saules, 2013). These results suggest that one or more of the criteria included in the YFAS may be a behaviour endorsed by individuals with elevated body mass indexes (BMI).

2.4.1.2 Binge Eating Disorder and Bulimia Nervosa

Across all relevant studies, participants who met the YFAS criteria for an FA "diagnosis" were significantly more likely to also fulfil Binge Eating Disorder (BED) criteria, supporting similar findings by Davis, Curtis, et al. (2011). The highest prevalence amongst individuals with BED was reported by Gearhardt, White, et al. (2012) and reached 56.8%, whilst the highest mean YFAS symptom count of 4.56 in a sample with BED was reported in the same study.

The prevalence of a "diagnosis" of FA according to the YFAS was found to be greater still in patients with Bulimia Nervosa (BN). For example, Gearhardt, Boswell, et al. (2014) reported the prevalence of FA in BN patients to reach 83.6%, compared to 47.2% in individuals with BED. Additionally, in a study conducted by Meule, von Rezori, et al. (2014), all twenty-six of the patients with current BN scored sufficiently on the YFAS to qualify for a FA "diagnosis", compared with only 30% of remitted BN participants and none of the healthy control group. These results indicate that binge eating behaviour, with or without compensatory behaviours, is strongly associated with the criteria defined by the YFAS.

2.4.1.3 Adult general population

In the nineteen studies which reported the prevalence of YFAS-defined FA in the general population, the prevalence ranged from 0% (Meule, von Rezori, et al., 2014) to 8.7% (Brunault et al., 2014) whilst the mean YFAS symptom count ranged from .86 (Meule, von Rezori, et al., 2014) to 3.05 (Gearhardt, Boswell, et al., 2014). These results suggest that endorsement of the YFAS criteria is not unique to those individuals with clinically-recognised eating disorders or an overweight or obese BMI.

2.4.1.4 Children

Only one study reported the prevalence of a YFAS diagnosis in children (Gearhardt, Roberto, Seamans, Corbin, & Brownell, 2013). In this sample of 75 children, 7.2% met the YFAS diagnostic criteria. This study utilised the adapted version of the YFAS for children (YFAS-C), adapted from the original YFAS by referring to age-appropriate activities and adapting the questions to a lower reading grade. In this study, the YFAS-C was reviewed for clarity by a panel with expertise in addiction and childhood obesity and includes twenty-five questions which relate to the same diagnostic criteria as the original YFAS.

Additionally, in two retrospective studies (Mason et al., 2013; Mason et al., 2014), a positive association was found between the likelihood of endorsing a YFAS diagnosis in adulthood and experiencing physical abuse, sexual abuse or post-traumatic stress disorder (PTSD) in childhood or adolescence. Furthermore, Davis, Curtis, et al. (2011) reported a significant association between an adult YFAS "diagnosis" and those retrospectively meeting the criteria of a probable diagnosis of childhood ADHD.

2.4.2 Correlates of food addiction

Across all reviewed studies, a range of psychometric and demographic measures were assessed and their relationships with YFAS diagnoses were considered and quantified. The most commonly implicated outcome measures will be discussed further.

2.4.2.1 Body Mass Index

The majority of studies measured BMI within the sample, but not all reported the relationship between the YFAS and BMI. In studies recruiting participants with a range of BMIs (N=18), YFAS "diagnosis" was found to be positively correlated with a higher current BMI (Granero et al., 2014) and a greater maximum reported adult BMI (Gearhardt, Boswell, et al., 2014). Specifically, Mason et al. (2013) reported that female nurses meeting YFAS diagnostic criteria for FA were 6 BMI units (kg/m2) heavier than those who did not meet the criteria, supporting the conclusions of Flint et al. (2014) that those meeting a YFAS diagnosis are more likely to be overweight. In addition to this, Pedram et al. (2013) reported that when individuals endorsing the YFAS criteria were classified according to their BMI, 11.4% of the so-called 'food addicts' were under- or normal weight whilst 88.6% were overweight/obese. A relationship between YFAS diagnosis and BMI was also found in children, whereby elevated scores on the YFAS-C were significantly positively correlated with higher BMI.

Conversely however, no difference in BMI between YFAS-diagnosed 'food addicts' and 'non-food addicts' was reported by Meule and Kübler (2012a) in a sample with a wide range of BMIs. A similar finding was reported in a sample where BMI fell within a healthy range (Meule, Lutz, Vögele, & Kübler, 2012). Similarly, Gearhardt, Yokum, et al. (2011) and Eichen et al. (2013) found no correlation between BMI and YFAS scores, however; subjects who reported binge eating or compensatory behaviours were excluded from the sample. Additionally, Burgess, Turan, Lokken, Morse, and Boggiano (2014) reported that YFAS scores did predict some of the variance in BMI in their college sample, but this association disappeared after binge eating scores were controlled for. Competing interpretations of this finding support either a moderating role for binge eating in the association between YFAS diagnosed food addiction and BMI, or that YFAS items may be confounded with binge eating scores and explain no additional variance.

2.4.2.2 Binge Eating Behaviour

Seventeen studies measured binge eating (BE) behaviour in overweight or obese samples (N=11), the general or healthy population (N=5) and patients with eating disorders (N=2). Results were consistent across studies, demonstrating that those meeting the YFAS criteria for FA were more likely to report BE behaviour (for example, Clark & Saules, 2013; Gearhardt, Boswell, et al., 2014) or meet criteria for a BED diagnosis (Brunault et al., 2014; Davis, Curtis, et al., 2011). For example, among subjects who met the YFAS "diagnosis", 28.9% also endorsed clinical criteria for BED, compared with 4.1% of those who didn't fulfil YFAS criteria (Imperatori et al., 2014).

Specifically, so-called 'food addicts' reported more frequent BE episodes whereby number of binges per week was found to be correlated with YFAS score (Gearhardt, White, et al., 2012; Granero et al., 2014; Meule, Hermann, & Kubler, 2015). YFAS symptom count was a significant correlate of frequency of BE episodes, even after controlling for troubled and emotional eating (Gearhardt et al., 2009b). A dichotomous YFAS diagnosis was also identified as a significant predictor of the frequency of BE episodes in overweight or obese BED patients (Gearhardt, White, et al., 2012). Furthermore, contrary to the results of Boggiano et al. (2014), YFAS score accounted for 11.1% of unique variance in binge eating episodes after controlling for the variance accounted for by depressive mood and eating disorder psychopathology in one study (Gearhardt, White, Masheb, & Grilo, 2013). In addition to this, YFAS symptom count correlated significantly with BE scores in both overweight patients and healthy weight controls (Boggiano et al., 2014).

2.4.2.3 Psychological Wellbeing

Given the aforementioned compromised psychological wellbeing commonly associated with substance addictions, for “food addiction” to warrant classification as an ‘addiction’ it should be assumed that a clinical level of psychological impairment should exist. As such, twenty seven of the included studies have investigated associations between YFAS-defined FA and various markers of psychological wellbeing. These include depression (N=10), general psychopathology (N=2), substance (N=6) and alcohol (N=6) use, ADHD (N=1), PTSD (N=1) and physical or sexual abuse in childhood or adolescence (N=1).

The relationship between YFAS “diagnoses” and depression has generated mixed results. Several studies have reported a positive association between depression and both a dichotomous YFAS score (Eichen et al., 2013; Flint et al., 2014; Meule, Heckel, Jurowich, Vögele, & Kübler, 2014; Meule, von Rezori, et al., 2014) and YFAS symptom count (Burmeister et al., 2013; Meule & Kübler, 2012a), whilst self-reported ‘food addicts’ have been reported to have a significantly higher prevalence of severe depression compared with ‘non-food addicts’ (Davis, Curtis, et al., 2011). Such effects have persisted even in studies where subjects with major depressive disorder (MDD) were excluded (Eichen et al., 2013). However, this association has not been consistently replicated, with some studies failing to report an association between YFAS diagnosis and mood disorders, negative affect and emotion dysregulation (Gearhardt, White, et al., 2013). For example, in a study on overweight and obese patients seeking weight loss therapy by Imperatori et al. (2014), it was reported that the relationship between YFAS diagnosis and psychopathology was fully accounted for by binge eating severity, therefore suggesting a greater importance of binge eating in psychopathology, compared to YFAS-defined FA.

Researchers have investigated the relationship between so-called food addiction and clinically defined substance use disorders, such as alcohol and drug dependence. Again, findings have been mixed with some researchers reporting an association between YFAS “diagnosis” and problematic substance use (Clark & Saules, 2013) and alcohol use (Gearhardt et al., 2009b). However, in two samples of overweight or obese adults, no correlation between YFAS diagnosis and alcohol or drug use was reported (Gearhardt, White, et al., 2013; Gearhardt, White, et al., 2012), whilst Meule, Heckel, et al. (2014) found that subjects endorsing YFAS criteria had lower scores on the Alcohol Use Disorder Identification Test (AUDIT).

A possible role of weight-loss in inducing FA symptomatology has been reported, whereby one study comprising a sample of 141 adults post weight loss surgery reported those meeting a pre-surgical YFAS “diagnosis” were more likely to report problematic substance use post-surgery (Reslan, Saules, Greenwald, & Schuh, 2014). Furthermore, those participants reporting post-surgery problematic substance use were found to lose less weight. The authors argued that YFAS assessment of food addiction pre-surgery could help to prevent post-surgery substance use, a process consistent with “addiction transfer” (Reslan et al., 2014).

In the studies reporting ADHD, PTSD and sexual or physical abuse in childhood or adolescence (Davis, Curtis, et al., 2011; Mason et al., 2013; Mason et al., 2014), such disturbances were all found to be risk factors for so-called food addiction in adulthood. The likelihood of a YFAS diagnosis was further amplified if the abuse or trauma began at a younger age or lasted longer, suggesting a potential antecedence of psychological disturbance in childhood or adolescence in the presence of so-called food addiction in later life.

2.4.2.4 Weight Loss Outcomes

Twelve studies were reviewed that focused on the relationship between YFAS diagnostic criteria and weight loss. Of these, the majority (N=9) recorded patients seeking weight loss treatment or bariatric surgery, whilst one reported patients currently undergoing treatment and two measured samples post treatment. Findings in this area were mixed. For example, Lent, Eichen, Goldbacher, Wadden, and Foster (2014) reported that, after controlling for treatment type, baseline weight and sex, YFAS symptom count did not significantly contribute to the variance in weight change following treatment. Furthermore, the presence of a dichotomous YFAS diagnosis at the start of the weight loss intervention study did not reduce subsequent weight loss, with patients who met YFAS criteria losing comparable amounts of weight as those who did not.

Interestingly, surgery-induced weight loss was reported to induce a remission in YFAS diagnoses in 93% of obese/overweight so called food addicts (Pepino et al., 2014). In contrast, however, Burmeister et al. (2013) reported that those individuals with a YFAS diagnosis showed a reduced weight loss after a seven week intervention. A similar, but non-significant effect, was also found by Clark and Saules (2013). These results outline the uncertainty of the status of “food addiction” in the treatment of obesity and cannot conclusively determine whether a YFAS diagnosis provides any useful information in a weight loss setting.

2.5 Discussion

The present systematic research review aimed to critically explore the existing literature investigating the prevalence and correlates of so-called food addiction, as measured by the Yale Food Addiction Scale, in order to increase understanding of its status as a hypothesised condition. Interpretation of the findings are discussed below, along with critical issues encountered.

2.5.1 Prevalence and correlates of food addiction

The prevalence of so-called food addiction, as defined by the YFAS, has been reported in numerous populations across the present literature. The highest prevalence rates of YFAS "diagnoses" were found in samples of overweight or obese individuals. However, contrary to some researchers' assumptions, the increased prevalence of a YFAS diagnosis in these samples does not validate the existence of food addiction as a novel behavioural phenotype which explains overconsumption. It is premature to suggest that FA plays a causal role in the development of obesity, as the vast majority of the studies reviewed relied on cross-sectional designs, a point which is also acknowledged in the review by Pursey, Stanwell, Gearhardt, et al. (2014) as clouding "interpretation of cause and effect among variables" (p. 4582). The label of FA may become attached to people predisposed to become obese due to a positive energy balance arising from multiple features of the obesogenic environment.

Similarly, high YFAS prevalence rates were identified in samples who engaged in binge eating behaviour. This has prompted authors to propose that so-called food addiction may be an atypical subtype of binge eating disorder (BED). Nonetheless, the prevalence of YFAS diagnoses in obese samples with BED generally failed to reach 50% (for example, Gearhardt, White, et al., 2013), suggesting either that so-called FA is not synonymous with BED or obesity and therefore warrants consideration as a unique condition, or, equally, that the YFAS does not capture the full spectrum of heterogeneity that characterises the experience of individuals with BED. The question of whether a label of FA contributes any unique variance to the identification of Binge Eating is an important issue that needs to be clarified.

Indeed, it has been argued that so-called food addiction may be an extreme subtype of binge eating disorder. Support for this idea comes from research by

Davis et al. (2013) who reported that a dopaminergic genetic profile could differentiate between those obese individuals who received a YFAS diagnosis and those who did not. This notion is further supported by Imperatori et al. (2014) who noted that, although the prevalence of a YFAS “diagnosis” in obese samples with BED was very high, the prevalence was lower when studying obese populations without BED. The authors concluded that an atypical binge eating phenotype may exist in a small subgroup of obese individuals who also manifest other symptoms which are better captured by the YFAS compared to the Binge Eating Scale. It should also be considered whether the relationship between binge eating and so-called food addiction may be moderated by BMI, in that FA symptomatology is more likely to be present in individuals who engage in binge eating behaviour and also have a high BMI, an argument presented by Filbey, Myers & DeWitt (2012).

However, even the most conservative prevalence estimates are still much higher than would be expected if so-called food addiction were simply a subtype of BED. Whether this suggests that FA be a less extreme subtype of BED, or conversely that it is in fact distinct from BED to a greater extent than primarily suggested, will be explored in detail in Chapter 4. To suggest that an obese individual who meets a YFAS “diagnosis” is at greater risk than a BED patient who does not remains unsubstantiated.

Moreover, attempts to draw parallels between substance dependence and binge eating are restricted due to the differences in core psychopathology between these disorders. As suggested by Meule, von Rezori, et al. (2014), in binge eating and other eating disorders, concerns regarding body weight and shape often drive dysfunctional eating patterns which, in turn, lead to binge eating episodes and possible compensatory behaviours. Such aspects are absent in other addictive behaviours like compulsive drug taking, rendering similarities between drug and so-called food addiction tentative. Even when investigations are restricted to BED samples, many characteristics which are essential for diagnosis of substance dependence are not fully applicable to eating behaviours. For example, tolerance and withdrawal are particularly difficult to discern from processes of hunger and satiety when related to eating behaviour (Eichen et al., 2013; Meule & Kübler, 2012b; Ziauddeen & Fletcher, 2013). This idea is supported by Ziauddeen and Fletcher (2013) who concluded that the inconsistent nature of reported similarities between obesity, binge eating and so-called food addiction reflects the limited applicability of the ‘food addiction hypothesis' which may be better represented – and already accounted for – by binge eating.

This idea can be extended to explain the high prevalence of YFAS diagnoses in patients with bulimia nervosa. Such a prevalence could be attributed simply to the overlapping symptoms between this condition and binge eating disorder (Boggiano et al., 2014). Few data are available with only 3 studies investigating the prevalence of YFAS-defined FA in Bulimia Nervosa patients. Interestingly, BN has been described as an extreme form of BED (C. G. Fairburn, Cooper, Doll, Norman, & O'Connor, 2000) with additional compensatory behaviours (such as purging, laxative use, excessive exercise). This may explain the increased prevalence of YFAS "diagnoses" seen in BN patients but also demands investigation over whether so-called food addiction in and of itself has a role as a biological cause of overeating.

2.5.2 Measuring food addiction

Few instruments other than the YFAS have been utilised to measure addictive eating behaviour (Meule, 2012). The Eating Behaviours Questionnaire developed for paediatric samples, for example, consists of 20 hypothesised symptoms of "food addiction" based on adaptations of DSM-IV criteria for substance dependence (EBQ; Merlo, Klingman, Malasanos, & Silverstein, 2009). Furthermore, Goodman (1990) broadened the diagnostic criteria for addictive disorders and assessed women with binge eating disorder (Cassin & von Ranson, 2007), yet the authors concluded that the classification of BED should remain an eating – rather than an addictive – disorder. However, the most commonly used tool to quantify the proposed food addiction symptomatology at present is the Yale Food Addiction Scale itself. This poses problems in disentangling the existence of so-called food addiction as a clinical entity from the psychometric measurement of "food addiction" provided by the YFAS. The assessment of FA using the YFAS has fuelled support for its existence as a valid clinical condition (Ziauddeen et al., 2012b), despite diagnoses being based solely on self-report responses, frequently in individuals who are motivated to assign responsibility for their problematic eating behaviour to factors beyond their control.

One feature of the YFAS is the inclusion of two items designed to indicate 'clinical impairment', which must both be met in order to warrant an affliction on a similar level as would be expected in a drug-addicted individual. However, few studies have actually investigated the level of clinical impairment experienced by individuals who meet a YFAS “diagnosis” (Davis, Curtis, et al., 2011). Instead, researchers tend to favour the YFAS symptom-count score as it yields more power to detect relationships in small samples (Burmeister et al., 2013), despite there being a lack of evidence to support this continuum (Ziauddeen & Fletcher, 2013). Moreover, the use of a single instrument (the YFAS) to identify FA introduces the possibility of a circular argument. To the question: “why is this person a food addict?”, the answer is: “because of a high score on the YFAS”. But to the question: “why does this person score high on the YFAS?”, the answer is: “because they are a food addict”. The circularity of this deduction can only be broken by the assignation of separate behavioural symptoms of FA that are independent of YFAS scores.

The present review identified limitations in the methodologies adopted to examine the context of so-called food addiction. Only three studies (Davis, Levitan, Kaplan, Kennedy, & Carter, 2014; Gearhardt, Yokum, et al., 2011; Pedram et al., 2013) analysed the YFAS and its relationship with actual food choice or intake. This weakens the argument suggesting that certain foods or food groups may be addictive (Avena et al., 2008; Schulte et al., 2015) as behavioural evidence in human populations to support such claims is not yet established, a limitation which will be assessed further in Chapter 6 and Chapter 7. Conducting laboratory and free-living methodologies to assess actual human food intake in relation to scores on the YFAS will help to advance and balance the research in this field. Furthermore, several authors have adopted language in their studies which appears to confirm the existence of so-called food addiction, such as “hyper-palatable” and “addictive response”. Just like the term “food addiction” itself, these terms do not have a clear definition and seem to instead be used to layer a biased interpretation on top of otherwise neutral data.

2.5.2.1 Identifying ‘addictive’ foods

Many researchers are turning their attention to identifying specific foods or ingredients which may have the ability to trigger a so-called addictive response in susceptible individuals. Such ‘addictive agents’ (Schulte et al., 2015) include refined carbohydrates, fat and salt, often in combination and are frequently associated with excessive consumption (Weingarten & Elston, 1991). Many of these foods, such as chips, pizza, pastries, savoury snacks and soda pop

(Gearhardt et al., 2009b), are listed on the YFAS. It is unsurprising, therefore, that patients with BED often identify foods high in these ingredients as triggering binge eating episodes (Davis, Curtis, et al., 2011). However, the extrapolation of these limited reports to support the idea that highly processed foods can trigger an addiction is as yet unwarranted, given that the majority of these outputs rely on a very small number of studies conducted in animal models, as discussed in Chapter 1. At this stage, the most scientifically secure conclusion is that the availability and consumption of palatable foods has the potential to alter behaviour and activate the neural circuitry implicated in food reward.

2.5.3 Limitations

Though novel, this systematic review is not without its limitations. The majority of studies included used the general population or those who were overweight as their samples, therefore findings regarding studies with limited samples, such as children or those seeking weight loss surgery, should be interpreted with caution. Further, study samples were predominantly female, limiting generalisability of the findings to males. Finally, this study would have benefitted from a meta-analysis of the prevalence of YFAS ‘diagnoses’ in various populations, as conducted by Pursey et al. (2014).

2.5.4 Conclusions

This systematic review of forty studies is the largest at time of writing and has uncovered mixed results regarding the prevalence and correlates of so-called food addiction. Notably, YFAS scores were higher in overweight or obese samples or those with binge eating disorder, prompting researchers to conclude that “food addiction” may be a subtype of BED, reflecting many of the problematic eating behaviours endorsed by those who have been unsuccessful in controlling their weight.

Summary

- The prevalence of FA “diagnoses” were revealed to be consistently greater in overweight and obese samples, relative to normal or underweight individuals.
- Participants who met the YFAS criteria for an FA “diagnosis” were also significantly more likely to fulfil Binge Eating Disorder (BED) criteria.
- However, the relationship between FA and BMI was mixed, with 6 studies finding a positive association and 5 studies reporting no association.
- A similarly mixed association was revealed between the YFAS and measures of psychological wellbeing, with 3 studies recording a positive association whilst a further 3 found no association
- Much of the literature made the supposition that food addiction is a valid clinical disease, despite this interpretation being based on very limited data and a weak diagnostic tool.
- Further research is required to determine whether FA is sufficiently different from existing validated models of overeating to warrant classification as a distinctive condition.

2.6 Update to the Systematic Research Review

2.6.1 Methods

The literature search included in Chapter 2 was replicated in June 2017 in order to ensure that all literature included in the present thesis was up to date. The same key terms and limits were applied to Embase, PsycINFO, MEDLINE, Science Direct and Web of Science, but searches were limited from 2015-present, to prevent overlap with the literature identified in Chapter 2. A full description of the methodology is included in section 2.3.

2.6.1.1 Inclusion and exclusion criteria

As in section 2.3.3, no exclusion criteria were applied to sample demographics. Only experimental studies were included, thus all review papers (N=55), case studies (N=1), commentaries (N=7) or non-experimental uses of the YFAS (N=7) were excluded. Only peer-reviewed articles were included, thus dissertation and thesis papers (N=4), abstracts (N=13), conference abstracts (N=27) and books (N=4) were excluded. Those not in English (N=5) or not in humans (N=6) were also excluded.

2.6.1.2 Data extraction

465 studies were initially identified using the predefined search strategy. A flowchart outlining the data extraction method is presented in *Figure 2*. After applying the exclusion criteria, removing duplicated articles and literature already identified in Chapter 2, 60 relevant studies met the predefined criteria for inclusion in this analysis. Results were summarised according to two main categories: Prevalence and Correlates, and a summary of results is included in Appendix B.

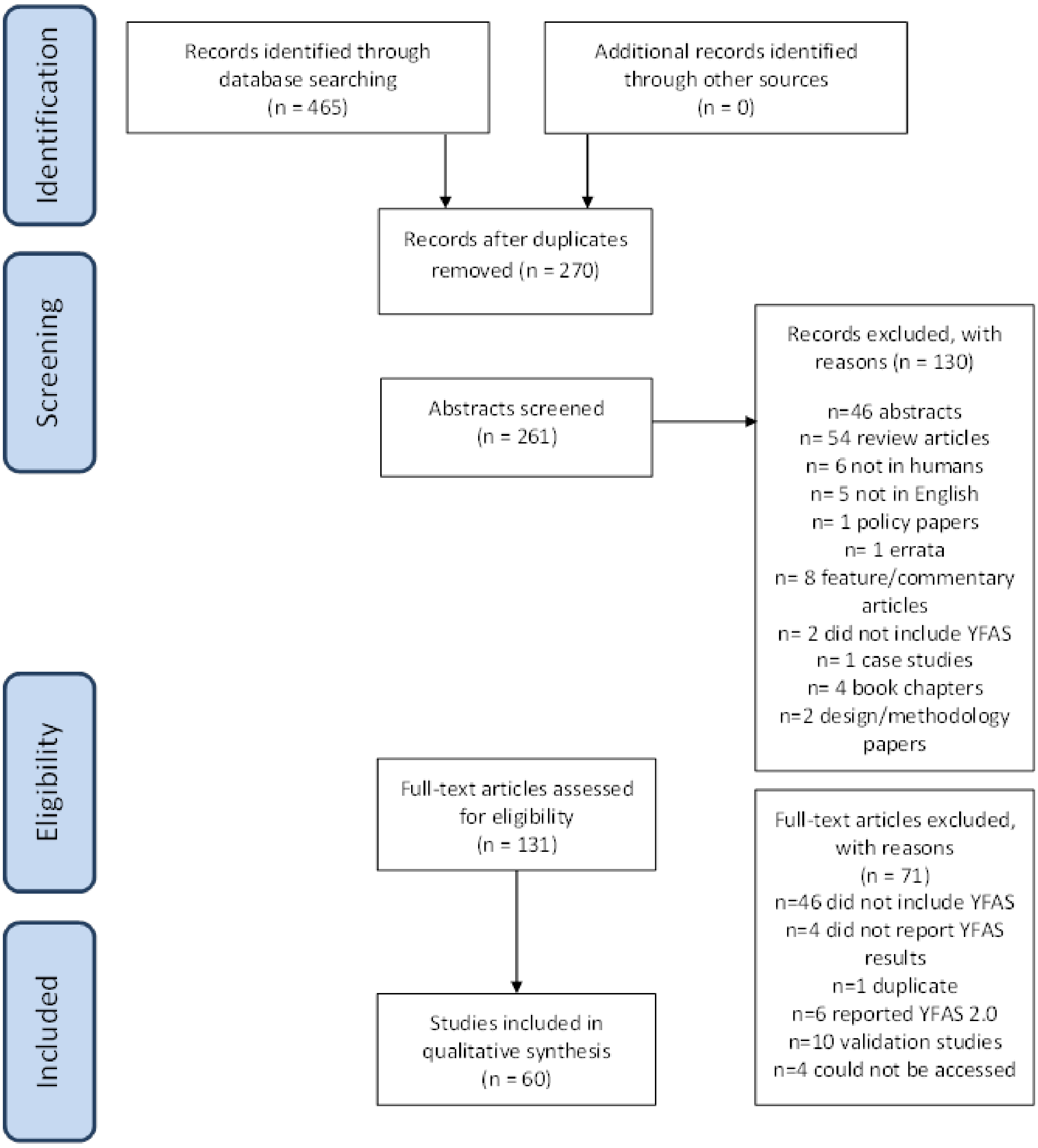

Figure 2. PRISMA Flowchart depicting the search strategy for the SRR amendment

2.6.2 Results

The findings from this update generally supported those of the primary review, revealing a similarly positive relationship between YFAS scores and binge eating behaviours. However, mixed results regarding YFAS scores in overweight and obese samples was identified. For example, one study reported a small (6.70%) prevalence of FA in weight loss treatment-seeking obese individuals, whilst another study reported a prevalence of FA of 34.10% in a comparable sample.

The amended systematic review revealed a more clear relationship between YFAS scores and poor psychological wellbeing. A consistent association between YFAS scores and depressive symptoms, anxiety, reduced quality of life and emotion regulation was found, as well as the novel finding in a sample of adolescent psychiatric inpatient females. In this sample, 16.50% met the YFAS criteria for FA and 42.50% met the criteria for an eating disorder (ED). YFAS score was significantly higher in patients with undereating disorders, suggesting a non-linear relationship between FA 'diagnoses' and BMI.

2.6.3 Discussion

A full discussion of the results is included in Chapter 8.

Chapter 3

A psychometric analysis of the Yale Food Addiction Scale

Aims

- To conduct a psychometric analysis to explore the factor structure of the YFAS.
- To confirm the factor structure of the YFAS in a large, independent sample of UK adults.
- To explore whether the factor(s) identified in the YFAS relate to the theoretical construct of 'food addiction' or to its proposed symptomatology.

3.1 Abstract

Background: The lack of a formal definition of food addiction (FA), coupled with discrepancies in the reporting of previous YFAS factor analyses raises questions about the psychometric properties of this scale. Although a one-factor structure has been reported in previous literature, a seven or eight-factor structure, representing the seven criteria from the Diagnostic and Statistical Manual (DSM) and the additional criteria measuring ‘clinically significant impairment or distress’ upon which the YFAS is based, might be expected.

Method: The present chapter therefore aimed to investigate the psychometric properties of the YFAS using a cross-sectional survey design in two large samples of UK adults (N=1019; mean age 30.13 (±12.15), 86.90% female (N=886); and N=667, mean age 26.27 (±11.05), 82.20% female (N=548). Both surveys formed part of larger surveys, and only complete responses to the YFAS were included in the analyses in this chapter.

Results: Confirmatory Factor Analyses did not support a one-factor structure of the YFAS, whilst a seven-factor structure representing seven of the DSM criteria was also found to have a poor fit of the present data. Subsequent Principal Components Analysis with Parallel Analysis was conducted in a second sample and a two factor model explaining 35.15% of the variance was revealed. Through item analysis, it was proposed that 5 items should be removed from the scale due to having factor loadings of less than .4. Confirmatory Factor Analysis tested the fit of this two-factor model and revealed two more items with poor factor loadings which were subsequently removed. This refined two-factor model had a satisfactory fit and improved all goodness-of-fit indices compared to the one- and seven-factor models. The final two constructs, tentatively suggested to reflect “drive to overeat” and “strength of food habits”, did not seem to contain items which reflected specific ‘addiction’-related behaviours towards overeating and demonstrated low internal reliability (Cronbach’s α = .67 and .58 respectively).

Conclusion: These results highlight the generally weak psychometric properties of the most widely used tool for measuring ‘food addiction’ and caution against its uncritical use in research.

3.2 Introduction

Where previously common use of the term ‘Food Addiction’ (FA) tended to refer to intense cravings for certain foods (Blundell et al., 2014), the introduction of the Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009b) has allowed a body of research to develop around the concept of FA as a distinct clinical syndrome. Central to this research is the assumption that individuals’ responses on this scale could be sufficient to define and ‘diagnose’ this proposed condition.

Efforts to evaluate the construct validity of FA have been made by conducting factor analyses of the YFAS, testing the assumption that the underlying factor(s) of the YFAS reflect the FA concept. A one-factor structure has been demonstrated in community (Brunault et al., 2014), University (Gearhardt et al., 2009b; Meule, Vögele, & Kübler, 2012) and obese (Gearhardt, White, et al., 2012; Meule, Heckel, & Kübler, 2012) samples. Similar results have been revealed in the French (Brunault et al., 2014), Chinese (Chen, Tang, Guo, Liu, & Xiao, 2015), German (Meule, Vögele, et al., 2012), modified Italian (Innamorati et al., 2015), Spanish (YFAS-S; Granero et al., 2014) and recently the Malaysian (Swarna Nantha, Abd Patah, & Ponnusamy Pillai, 2016) and Portuguese (P-YFAS; Torres et al., 2017) translations of the YFAS. A one-factor structure has also been demonstrated in the YFAS adapted for children (YFAS-C; Gearhardt, Roberto, et al., 2013) and the more recent version of the YFAS updated in line with the DSM-5 (YFAS 2.0; Gearhardt et al., 2016). Researchers have labelled this underlying factor ‘food addiction’, concluding, therefore, that the YFAS is a sufficiently valid tool for measuring FA.

However, the finding that the YFAS appears to demonstrate a one-factor structure does not legitimise the YFAS as a measure of FA (Rogers, 2017), particularly due to the inconsistencies in measurement and reporting the YFAS factor structure. For example, Brunault et al. (2014) conclude that a one-factor structure of the YFAS was found in their data. However, a parallel analysis (Horn, 1965) – one of the most robust methods for determining the number of factors to retain in factor analysis (Hayton, Allen, & Scarpello, 2004) – in fact supported a two-factor structure of the YFAS. Similarly, the Malaysian (Swarna Nantha et al., 2016) and Chinese (Chen et al., 2015) translations of the YFAS identified a one-factor fit of the data in a Principal Components Analysis, yet

Confirmatory Factor Analyses in these studies failed to support this one-factor structure. Similarly, Brunault et al. (2014) found that a two-factor model improved the explained variance over a one-factor model. Swarna Nantha et al. (2016) also failed to include parallel analysis to support their extracted factor structure, as did the original psychometric development of the YFAS (Gearhardt et al., 2009b), thus these authors' decision to retain a one factor model was based on a subjective scree test, rather than objective parallel analysis methodology. Moreover, numerous studies (Gearhardt et al., 2009b; Gearhardt, White, et al., 2012; Innamorati et al., 2015; Swarna Nantha et al., 2016) excluded the 'clinical impairment' items (items 15 and 16) from their Principal Components Analyses of the YFAS, despite these items contributing to the overall YFAS diagnostic score. Such findings show there is actually considerable uncertainty in the underlying factor structure of the YFAS.

Moreover, it is surprising that a one-factor structure of the YFAS has been identified given that the YFAS is based upon the seven symptomatic criteria extracted from the DSM-IV-TR and an additional criteria measuring 'clinically significant impairment or distress'. It would be conceptually more reasonable to expect a seven or eight factor structure of the YFAS, with one factor representing each of the DSM symptoms, and the items accounting for their scores loading onto these factors accordingly. This idea is yet to be empirically tested.

In light of this, the factor structure of the YFAS is presently uncertain and in need of further confirmation. Furthermore, it cannot be assumed that the construct(s) which the YFAS consists of are necessarily indications of an entity called FA. Whilst it is likely that individuals who endorse the YFAS criteria for FA experience disordered eating behaviours (Ziauddeen & Fletcher, 2013), whether these behaviours are indicative of an addiction is yet to be convincingly examined on an item-by-item basis. An analysis of the psychometric properties of the YFAS is required, in order to confirm the underlying factor structure of the YFAS in UK adults.

3.2.1 Objectives

The primary aim of the current chapter was to conduct a comprehensive psychometric analysis to explore the factor structure of the YFAS in two large samples of the UK adult population.

The secondary aim was to explore whether the factor(s) identified in this psychometric analysis relate to a unitary theoretical construct or multiple proposed symptomatology of ‘food addiction’.

In order to address these aims, the one factor structure of the YFAS identified in previous research was tested in one sample using Confirmatory Factor Analysis (CFA). All active YFAS items (i.e. those contributing to a YFAS score and not those intended to be primer items; items 17, 18 and 23), both including and excluding the two items which measure ‘clinical impairment’ (items 15 and 16), were loaded onto a single factor and the indicators of goodness-of-fit examined.

Additionally, the fit of the YFAS items on the 8 criteria for substance dependence as outlined in the DSM-IV-TR were assessed by loading the YFAS items onto their respective factors and examining CFA indices to determine the goodness-of-fit of this model. As the “use continues despite knowledge of adverse consequences” criteria only had one item which contributed to its score (item 19), this criterion was not considered a latent variable and excluded from the analysis. Thus, a seven factor fit was examined.

Subsequently, as no factor analysis of the YFAS has been conducted in a large UK sample to date, exploratory factor analysis with Principal Components Analysis (PCA) was conducted to examine the underlying component(s) of the YFAS, and to determine how each item contributes to these components in this sample. All ‘active’ items were included in the PCA. Finally, Confirmatory Factor Analysis on a separate sample was conducted to confirm the fit of this model identified in the PCA. Examination of the individual items contributing to this factor structure were examined to determine whether they related to the concept of FA. Finally, the internal consistency of the identified construct(s) were analysed using Cronbach’s α.

3.3 Methods

3.3.1 Participants

The samples from two studies (Chapter 5 and Chapter 4) were utilised for this chapter and will hereby be referred to as Sample 1 and Sample 2, respectively.

In both samples, participants were recruited via the School of Psychology Participant Pool Scheme, whereby participation resulted in course credits. University e-mailing lists were utilised and social media, blogs, and forums were used to advertise the survey website to a wider audience. The ability to enter a cash prize draw of £30 upon completion of the study was used as an additional incentive to take part. Ethical approval for both studies was granted by the University of Leeds School of Psychology ethics committee.

3.3.1.1 Sample 1

This sample was obtained from a larger survey measuring individuals' perceptions of food images, as described in detail in Chapter 5. As part of the survey, participants completed the Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009b). Only the responses from the YFAS were used in the present analyses.

Male and female adult (aged 18-65) residents of the UK were recruited (N=1796). Only those providing complete responses to the YFAS were included in the analyses resulting in a final sample size of N=1019. Of the final sample, the mean age was 30.13 (±12.15), 86.90% were female (N=886) and 62.80% were White British (N=640).

3.3.1.2 Sample 2

This sample was obtained from a larger survey measuring various psychometric indices of eating behaviour, psychological wellbeing and addictive personality traits, as described in detail in Chapter 4. As part of the survey, participants answered the YFAS. Only the responses from the YFAS were used in the analyses in this chapter.

Male and female adult residents of the UK were recruited (N=1257). Only those providing complete responses to the YFAS were included in the analyses (N=667). Of the final sample the mean age was 26.27 (±11.05), 82.20% were female (N=548) and 81.90% were White British (N=546).

3.3.2 The Yale Food Addiction Scale

This 25-item instrument is based upon the symptom criteria for substance dependence, as defined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR; American Psychiatric Association, 2000) and an additional two items that assess significant clinical impairment of distress as a result from overeating. A dichotomous “diagnosis” of food addiction occurs when at least three food addition symptoms are met and a significant clinical impairment is present. Alternatively a YFAS “symptom count” can be measured and given a score between one and seven, indicating the severity of the impairment. More recently, a continuous “sum-score” (Price et al., 2015, p. 206) of the 22 ‘active’ items has been adopted, applicable due to the one-factorial structure of the YFAS (Meule, Heckel, & Kübler, 2012), and allowing more direct comparisons to other eating behaviour scales.

3.3.3 Data analysis plan

Confirmatory factor analyses (CFA) were performed on Sample 1 using AMOS version 23.0 (IBM SPSS; Chicago, IL) to determine the goodness of fit indices of the one- and seven-factor models hypothesised from previous research, and to confirm the fit of the model identified in the subsequent Principal Components Analysis. Each item was restricted to load on a single factor and factors were allowed to correlate. Five goodness-of-fit indices were used to evaluate the model tested: factor loadings of .4 or above, chi-square test (χ^2), comparative fit index (CFI; Bentler, 1990), root mean square error of approximation (RMSEA; Browne, Cudeck, Bollen, & Long, 1993) and Tucker Lewis Index (TLI; Tucker & Lewis, 1973). The goodness-of-fit of a model can be characterised by values obtained from four criteria: a chi-square value which is not statistically significant, a CFI and TLI greater than 0.90, and a RMSEA that is smaller than 0.06 (Hu & Bentler, 1999). However, although the χ^2 test is a conceptually simple indicator of the congruity of the data and the model’s variance pattern, this test is highly susceptible to the influence of sample size, whereby a larger sample leads to a greater likelihood of the test becoming significant (Russell, 2002). Therefore, only if the model exhibits an adequate fit with regard to *all* of these incremental fit indices then it can be concluded that the model is an adequate representation of the underlying factor structure (Matsunaga, 2015). Comparison between models was tested using the Akaike Information Criterion (AIC) whereby a lower value indicates a comparatively better fitting model.

The factor structure of the YFAS was examined in Sample 2 using Principal Components Analysis (PCA). Data was analysed using SPSS statistics (IBM Corp; Armonk, NY) version 22.0. It was tested whether data met the requirements for exploratory factor analysis by using the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO; Kaiser, 1970) and Bartlett's test of sphericity. Factors with an eigenvalue of greater than 1 were extracted (Kaiser, 1960) and the final number of retained factors was determined using parallel analysis (Hayton et al., 2004; Horn, 1965). Any items which cross-loaded onto two or more factors at .32 or higher were excluded from the analyses (Matsunaga, 2015; Osborne & Costello, 2009). Oblique direct oblimin rotation with a delta of 0 was used as the factors were assumed to be correlated. In the factor analyses, only the 'active' items were included in the analyses, thus those items (17, 18, 23) intended to be 'primer' items were excluded (Gearhardt et al., 2009b). Internal consistency of the retained factors were determined by Cronbach's alpha (α) and examination of inter-item correlations. Results are expressed as mean (±SD) unless otherwise specified.

3.4 Results

3.4.1 Participant demographics

In Sample 1, 11.10% of the sample met the YFAS criteria for 'food addiction' (N=113). The mean 'symptom count' was 2.12 (±1.70), and the mean 'sum-score' was 3.33 (±3.35). In Sample 2, 7.60% of the sample met the YFAS criteria for 'food addiction' (N=51). The mean 'symptom count' was 1.88 (±1.45), and the mean 'sum-score' was 2.85 (±2.83).

3.4.2 Factor structure of the YFAS

3.4.2.1 One-factor structure

As a one factor structure has been identified in previous research (for example; Gearhardt et al., 2009b; Meule, Heckel, & Kubler, 2012), the fit of this model was tested on Sample 1 using Confirmatory Factor Analysis both including and excluding the ‘clinical impairment’ items (items 15 and 16). All items were loaded onto a single factor and goodness-of-fit indices were examined.

3.4.2.1.1 Including ‘clinical impairment’ items

The one-factor model was a poor fit of the data ($\chi^2_{(209)}$ = 1728.84, $p < .001$; CFI = .70, RMSEA = .09, TLI = .67, AIC = 1816.84). However, in this one-factor model, seven items had factor loadings below the recommended cut-off of .40 (items 4, 6, 10, 11, 12, 22, 24 and 25). In an attempt to improve the fit of the model, these items were removed and the analysis was re-conducted. The refined one-factor model remained a poor fit of the data ($\chi^2_{(77)}$ = 1052.63, $p < .001$; CFI = .74, RMSEA = .11, TLI = .70, AIC = 1108.63), as depicted in *Figure 3*.

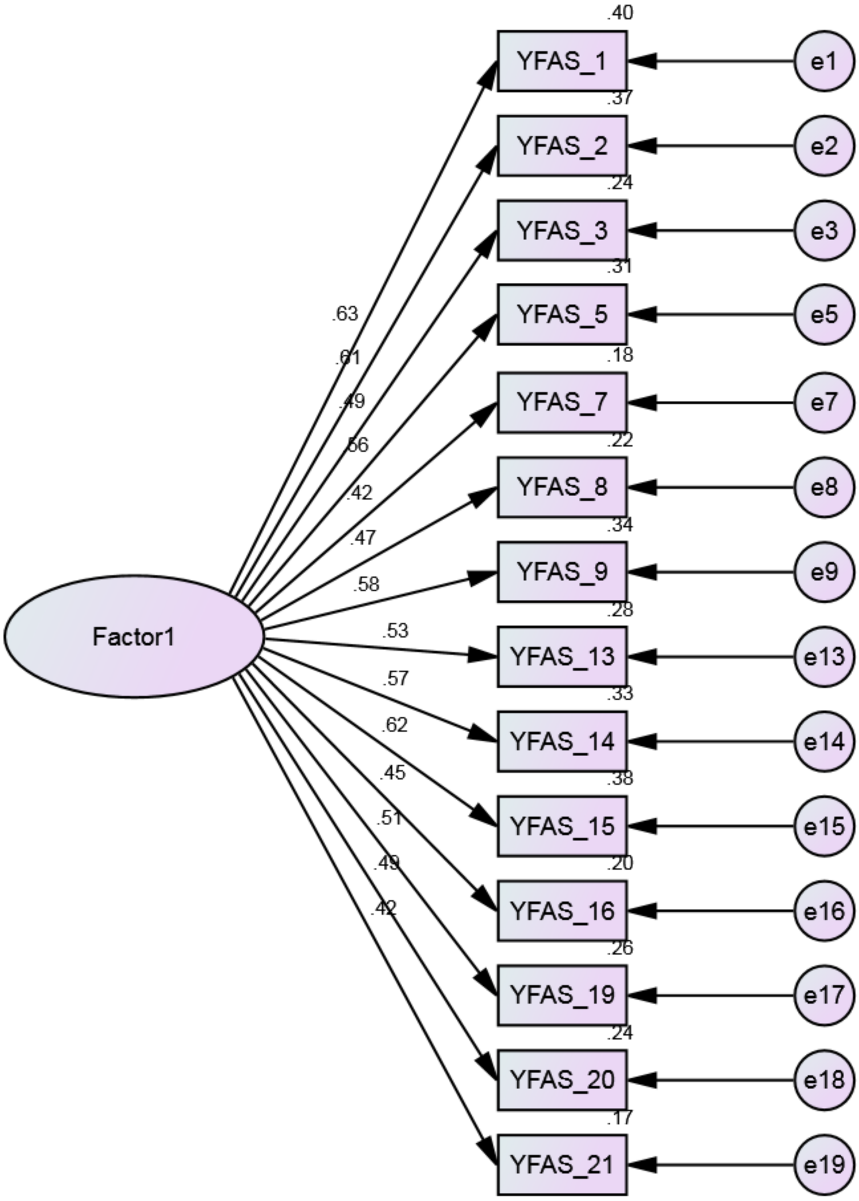

Figure 3. One-factor solution of YFAS, including 'clinical impairment' items (e = error) revealing a poor fit of the data ($\chi^2_{(77)}$ = 1052.63, p < .001; CFI = .74, RMSEA = .11, TLI = .70, AIC = 1108.63)

3.4.2.1.2 Excluding ‘clinical impairment’ items

When the ‘clinical impairment’ items (items 15 and 16) were excluded from the analyses, the one-factor model was a poor fit of the data ($\chi^2_{(170)}$ = 1347.34, p < .001; CFI = .71, RMSEA = .08, TLI = .68 , AIC = 1427.34). However, nine items had factor loadings below the recommended cut-off of .4 (items 4, 6, 10, 11, 12, 21, 22, 24 and 25) thus the analysis was re-conducted with these items removed in an attempt to improve the fit of the model. The refined one-factor model remained a poor fit of the data ($\chi^2_{(44)}$ = 529.73, p < .001; CFI = .82, RMSEA = .10, TLI = .77, AIC = 573.73) as depicted in *Figure 4*.

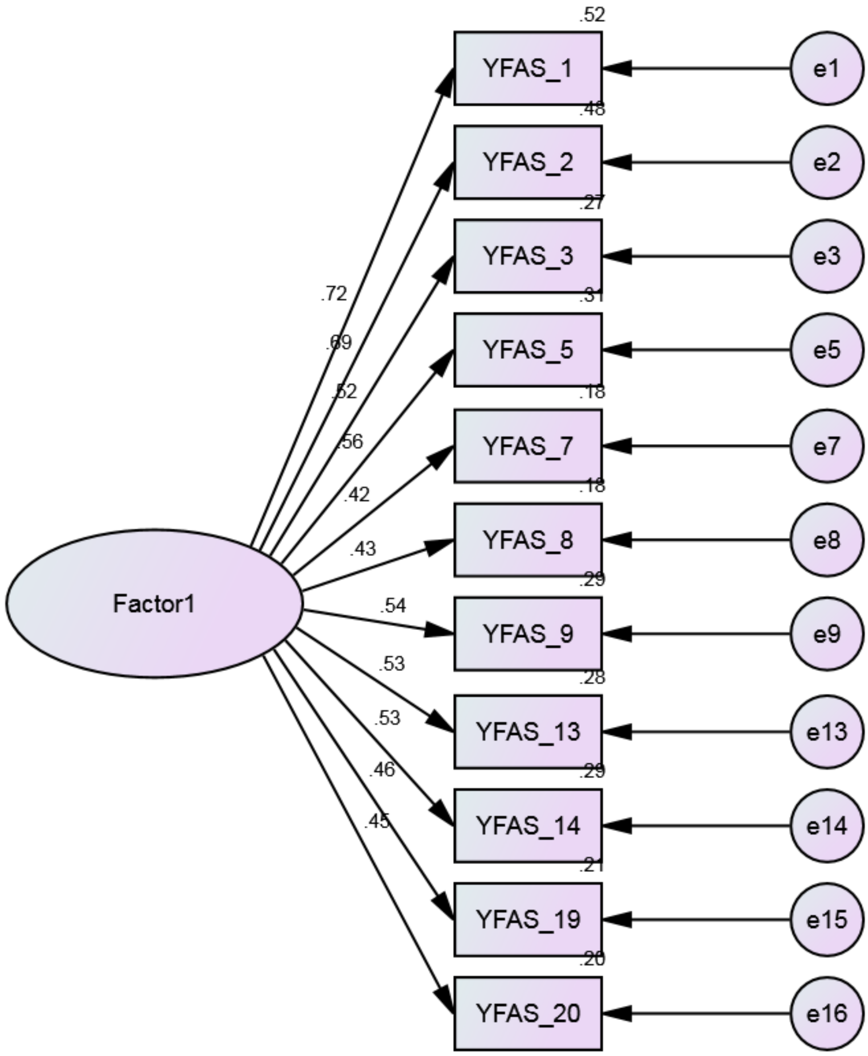

Figure 4. One-factor solution of YFAS, excluding 'clinical impairment' items (e = error) revealing a poor fit of the data (χ2(44) = 529.73, p < .001; CFI = .82, RMSEA = .10, TLI = .77, AIC = 573.73)

3.4.2.2 Seven factor structure

In order to examine the fit of the YFAS items onto the eight factors representing the diagnostic criteria in the DSM-IV-TR, all items were intended to be loaded onto their respective DSM-IV-TR criteria. However, as the “use continues despite knowledge of adverse consequences” criteria only has one item which contributes to its score (item 19), this factor and item could not be included in the analysis. The remaining seven criteria and their respective items were tested in a Confirmatory Factor Analysis on Sample 1. Each item was loaded onto its respective factor, factors were assumed to correlate and goodness-of-fit indices were examined.

The seven-factor model was a poor fit of the data ($\chi^2_{(168)}$ = 681.76, $p < .001$; CFI = .89 , RMSEA = .06, TLI = .86, AIC = 807.76). However, in this model, three items had factor loadings below .4 (items 6, 11 and 24). In an attempt to improve the fit of the model, these items were removed and the analysis was re-conducted. The refined seven-factor model improved the fit but remained a poor fit of the data ($\chi^2_{(114)}$ = 482.01, $p < .001$; CFI = .92, RMSEA = .06, TLI = .89, AIC = 596.01) as depicted in *Figure 5*.

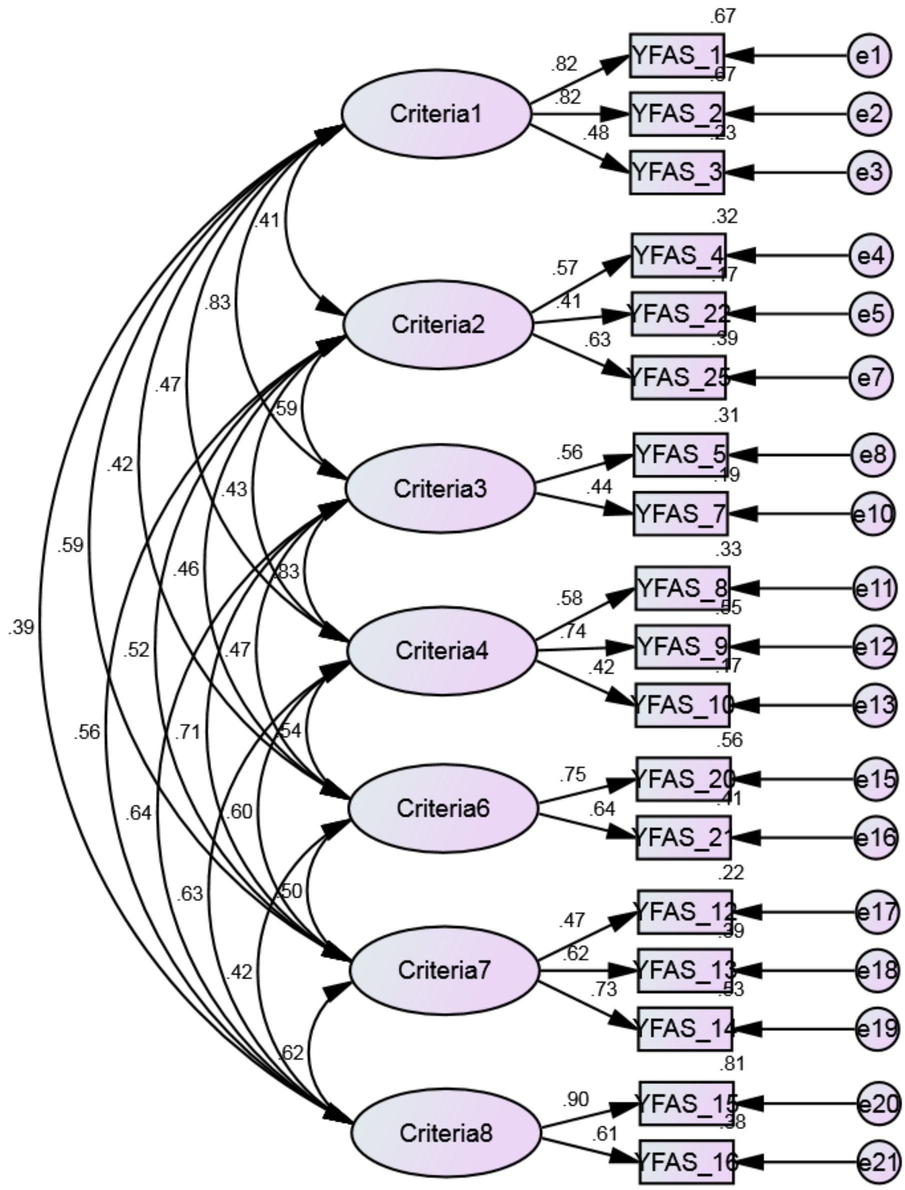

Figure 5. Seven-factor solution of YFAS (e = error; Criteria refer to the DSM-IV-TR criteria upon which the YFAS is based (Gearhardt, Corbin, & Brownell, 2012)), revealing a poor fit of the data ($\chi 2(114) = 482.01$, $p < .001$; CFI = .92, RMSEA = .06, TLI = .89, AIC = 596.01)

3.4.3 Principle components analysis (PCA)

As identified in the Confirmatory Factor Analyses, the underlying factor structure of the YFAS did not align with the one factor structure described in previous research, nor with the seven factor structure assumed to represent the seven of the eight criteria for substance dependence in the DSM-IV-TR which the YFAS is supposed to reflect. In response to this, the data were subsequently explored using a bottom-up, data-driven approach with Principal Components Analysis on Sample 2. There were no *a priori* hypotheses of the factor structure which could influence interpretation of the results.

The initial factor analysis for the 22 active items revealed that 1 item (item 24) did not strongly correlate with the other included variables and resulted in an increase in Cronbach's alpha if deleted (before α = .80, after α = .82, inter-item correlation = -.01). In accordance with previous work (Brunault et al., 2014; Chen et al., 2015; Gearhardt et al., 2009b; Innamorati et al., 2015), this item was excluded and analyses were conducted on the remaining 21 items.

Subsequent principal components and parallel analysis revealed a five factor model. However, the second factor only had two loading items (items 10 and 11), and factors with less than three items have been suggested to be "weak and unstable" (Osborne & Costello, 2009, p. 138). Additionally, item 4 cross-loaded onto factors 4 and 5 with loadings above .32 in both instances (Osborne & Costello, 2009). These items were consequently removed and the PCA was re-run with the remaining 18 items. The successive principal components analyses identified four factors with eigenvalues above 1. However, item 9 cross-loaded onto factors 1 and 4 above .32 on both factors. This item was removed and the PCA was re-run with the remaining 17 items.

In the final analysis, the Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis (KMO = .85) and all KMO values for individual items were above the acceptable limit of >.5 (Kaiser, 1974). Bartlett's test of sphericity indicated the correlations between data were adequate for conducting a principle components analysis ($\chi^2_{(136)}$ = 2372.87, p <.001). Initial analysis to obtain eigenvalues for each component in the data revealed four components had eigenvalues over Kaiser's criterion of 1 and, in combination, explained 48.67% of the variance. Eigenvalues before rotation were 4.58, 1.39, 1.16 and 1.14 respectively. After rotation they were 3.12, 2.55, 2.78 and 2.06. Factor loadings of the final seventeen items, corrected item total correlations and item statistics are presented in *Table 2*.

Table 2. Pattern Matrix displaying the factor loadings, corrected item total correlations and item statistics of the YFAS items included in the final PCA

Item	Item no.	Component				r_{itc}	Mean ±SD
		1	2	3	4		
I eat to the point where I feel physically ill.	3	.70				.43	.04 ±.19
There have been times when I consumed certain foods so often or in such large quantities that I started to eat food instead of working, spending time with my family or friends, or engaging in other important activities or recreational activities I enjoy.	8	.65				.49	.07 ±.25
I spend a lot of time feeling sluggish or fatigued from overeating.	5	.63				.48	.08 ±.27
I find that when certain foods are not available, I will go out of my way to obtain them, for example, I will drive to the store to purchase certain foods even though I have other options available to me at home.	7	.62				.36	.08 ±.27
I want to cut down or stop eating certain types of food.	22		.64			.30	.72 ±.45
I have found that eating the same amount of food does not reduce my negative emotions or increase pleasurable feelings the way it used to.	21		.58			.38	.18 ±.39
Over time, I have found that I need to eat more and more to get the feeling I want, such as reduced negative emotions or increased pleasure.	20		.56			.45	.12 ±.32
How many times in the past year did you try to cut down or stop eating certain foods altogether?	25		.55			.36	.24 ±.43
I kept consuming the same types of food or the same amount of food even though I was having emotional and/or physical symptoms.	19		.55			.41	.27 ±.45

I experience significant problems in my ability to function effectively (daily routine, job/school, social activities, family activities, health difficulties) because of food and eating.	16	-.75		.35	.02 ±.14
I have had withdrawal symptoms such as agitation, anxiety, or other physical symptoms when I cut down or stopped eating certain foods.	12	-.71		.29	.02 ±.12
My behavior with respect to food and eating causes significant distress.	15	-.58		.55	.09 ±.28
I have found that I have elevated desire for or urges to consume certain foods when I cut down or stop eating them.	14	-.47		.47	.10 ±.30
I find that when I start eating certain foods, I end up eating much more than planned.	1		.66	.52	.06 ±.24
I find myself continuing to consume certain foods even though I am no longer hungry.	2		.61	.45	.07 ±.26
I find myself constantly eating certain foods throughout the day.	6		.54	.19	.03 ±.18
I have consumed certain foods to prevent feelings of anxiety, agitation, or other physical symptoms that were developing.	13		.41	.48	.05 ±.21

Note: Some items include additional instructions which have not been included here for clarity. Response formats vary between items and, therefore, the dichotomised item score was used for all items. r_{itc} = corrected item total correlation

A scree plot and parallel analysis (*Figure 6*) indicated that of the four extracted factors, only the first two possessed eigenvalues above the randomly generated mean and 95th percentile eigenvalue. These factors contained four and five items respectively and, in combination, explained 35.15% of the variance in YFAS scores. Factor 1 contained items 3, 5, 7 and 8 and Factor 2 comprised items 19, 20, 21, 22 and 25. The two retained factors displayed a small positive correlation with one another (*r* = .24). The items within each factor were systematically examined in order to decipher common themes within the constructs and were tentatively interpreted as reflecting “drive to overeat” and “strength of food habits”, respectively. These construct labels were independently verified by two independent raters. The factors, their respective items and the DSM-IV-TR criteria are tabulated in Appendix C.

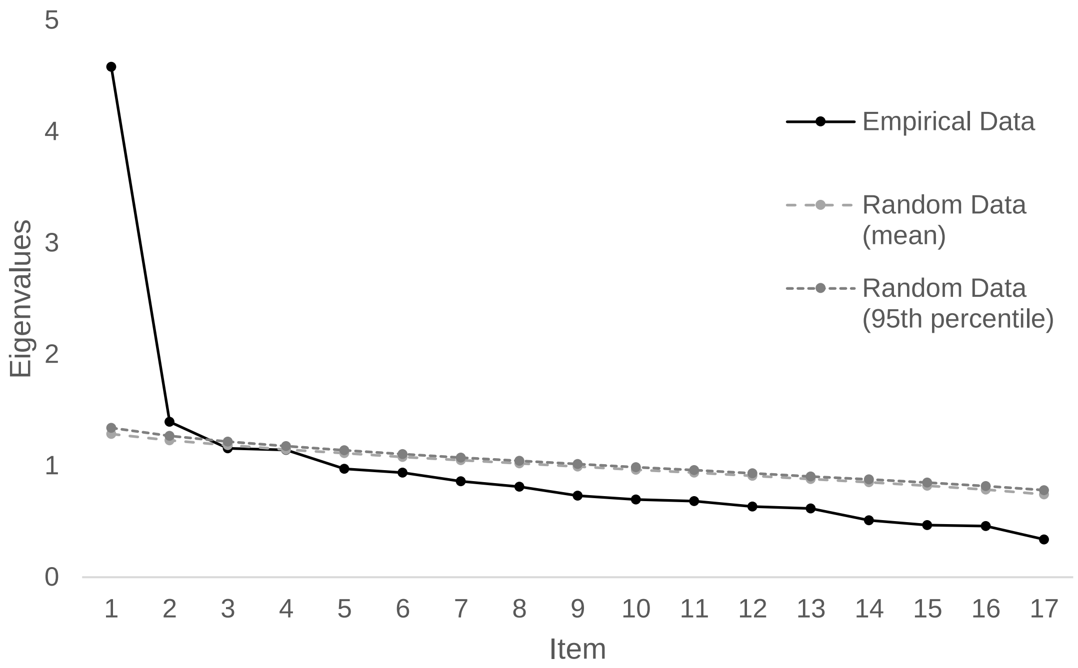

Figure 6. Scree plot and parallel analysis of eigenvalues

3.4.4 Confirmatory Factor Analysis of the model identified in the Principal Components Analysis

To determine the goodness of fit of the two-factor model identified in the PCA in Sample 2, Confirmatory Factor Analysis was again performed in Sample 1.

The fit of the two-factor model was acceptable ($\chi^2_{(26)}$ = 119.46, p < .001; CFI = .93, RMSEA = .06, TLI = .90, AIC = 157.46). However, two items (items 22 and 25) had factor loadings below the recommended cut-off of .4. In an attempt to improve the fit of the model, these items were removed and the analysis was re-conducted. The refined two-factor model improved all fit indices and was a satisfactory fit of the data ($\chi^2_{(13)}$ = 57.10, p < .001; CFI = .96, RMSEA = .06, TLI = .93, AIC = 87.10). Each item loaded significantly on its respective factor with factor loadings at or above .4 and the two factors correlated moderately with one another (r = .57). The two-factor CFA model is depicted in *Figure 7.*

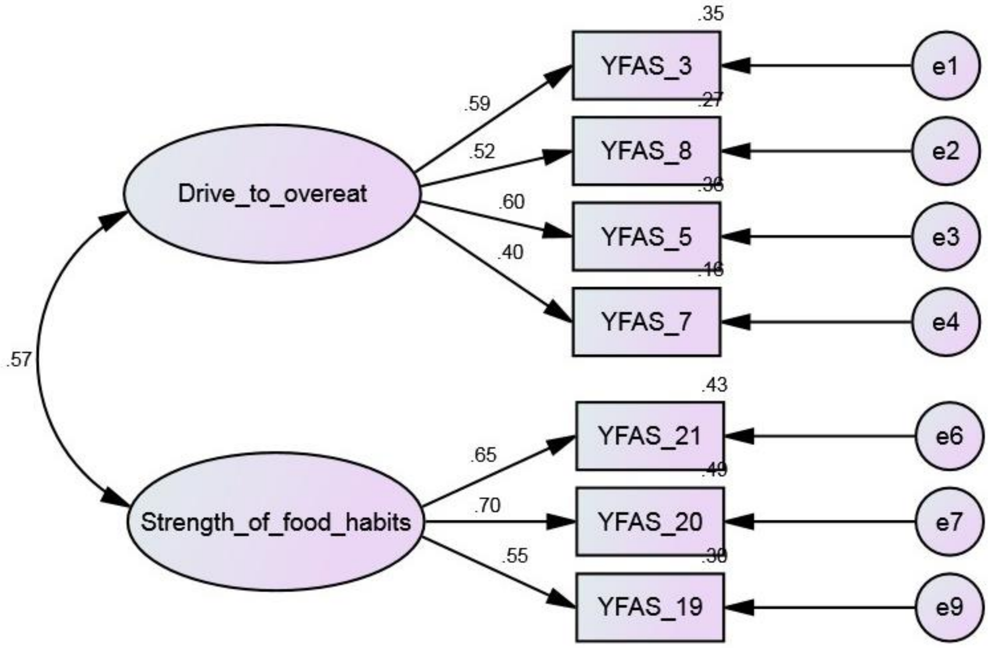

Figure 7. Two-factor solution of YFAS (e = error), revealing a satisfactory fit of the data ($\chi 2(13) = 57.10$, $p < .001$; CFI = .96, RMSEA = .06, TLI = .93, AIC = 87.10)

3.4.5 Internal reliability of the underlying constructs

The corrected item-total correlations for each item are presented in *Table 2* and ranged from .19 to .55. Regarding internal reliability, the Cronbach's alpha values for "drive to overeat" (items 3, 5, 7 and 8) and "strength of food habits" (items 19, 20 and 21) were .67 and .58 respectively.

3.5 Discussion

The present study aimed to assess the psychometric properties of the Yale Food Addiction Scale, including analysis of its factor structure in two large samples of UK adults. It was tested whether the underlying factor(s) of the YFAS map onto two contrasting conceptual models of food addiction: a one factor model presented in previous literature and a seven factor structure representing seven of the criteria for substance dependence on the Diagnostic and Statistical Manual (DSM), from which the YFAS originates. Previous factor analyses of the YFAS have been limited by sample size, demographic or shortcomings in statistical analyses and no thorough psychometric analysis of this scale has been performed in a UK sample, justifying the analyses in this chapter.

Given that previous research has tended to identify a one factor structure of the YFAS (such as; Brunault et al., 2014; Chen et al., 2015; Gearhardt et al., 2009b; Gearhardt, White, et al., 2012), initial Confirmatory Factor Analyses were conducted in order to test this model. Given their contribution to a food addiction 'diagnosis' according to the YFAS, this one factor structure was first tested including the two items (items 15 and 16) measuring 'clinical impairment'. A Confirmatory Factor Analysis revealed that the one-factor model was a poor fit of the data according to all goodness-of-fit indices, even when the model was refined to remove the low factor loading items. When items 15 and 16 were excluded in line with previous research, the fit of the model marginally improved according to the Akaike Information Criterion but was still a poor fit of the data, even when refined, according to goodness-of-fit indices.

One reason for the poor fit of a one factor structure could be explained by the fact that the YFAS is based upon the seven symptomatic criteria for substance dependence outlined in the DSM-IV-TR, plus an additional factor measuring clinically significant impairment. Thus, it was hypothesised that the YFAS may have an eight factor structure, with each of the items loading onto their respective factors as defined by Gearhardt, Corbin, et al. (2012). This idea was subsequently tested in a Confirmatory Factor Analysis, with each of the 'active' items loading onto its respective factor. As the "use continues despite knowledge of adverse consequences" criterion only had one item loading onto it (item 19), this factor could not be included in the model. Thus, a seven factor model was tested on the remaining 21 items. Results revealed that this seven-factor model was also a poor fit of the data as defined by the goodness-of-fit indices, even when refined to remove low factor loading items. Although the inability to include the “use continues despite knowledge of adverse consequences” criterion in this analysis limits these results, factors with fewer than 3 items are considered “weak and unstable” (Osborne & Costello, 2009, p.138). It should be considered that this factor is removed from the YFAS and whether item 19 aligns with one of the other criteria should be examined in future research.

The discrepancies in the results of the present study in the context of previous research therefore justified a data-driven analysis of the factor structure of the YFAS in a separate sample using Principal Components Analysis. After refining the model, removing those items with poor psychometric properties (items 24, 10, 11, 4 and 9), a four factor structure was identified in the remaining 17 items. Objective parallel analysis, rather than a subjective scree test, revealed that only two of these factors should be retained, comprising only 9 items in combination, explaining 35.15% of variance and undermining both the one-factor structure found in previous literature (for example; Brunault et al., 2014; Chen et al., 2015; Gearhardt et al., 2009b; Gearhardt, White, et al., 2012; Meule, Heckel, & Kübler, 2012) and the eight factor structure upon which the construction of the YFAS was based (Gearhardt et al., 2009b). The fit of this two-factor model was confirmed by a subsequent Confirmatory Factor Analysis in a separate yet demographically similar sample. Goodness-of-fit indices revealed a satisfactory fit of the two factor solution which was far superior to the one- and seven-factor structures previously tested.

In the present study, the two constructs retained by the PCA were interpreted as reflecting “drive to overeat” and “strength of food habits”. Whilst the labelling of these factors involved a degree of subjectivity, and factor names may not accurately reflect the items within the construct (Yong & Pearce, 2013), good scientific practice dictates that each of the uncovered components in PCA must be labelled, and in this case, the construct labels were independently reviewed by two raters. Whilst “drive to overeat” and “strength of food habits” are undoubtedly important phenomenological parameters for many individuals struggling to control their food consumption, neither of these factors seem to sufficiently encompass the compulsive nature of any behaviours indicative of a ‘food addiction’.

Interestingly, a recent study conducted by Ruddock, Christiansen, Halford, and Hardman (2017) aimed to develop a new ‘addiction-like eating behaviour scale’ (AEBS) and the authors’ factor analysis revealed a two-factor structure of this questionnaire. These two factors were labelled as “appetitive drive”, which aligns closely to the “drive to overeat” construct found in the present chapter, and “low dietary control”, which is less associated with the “strength of food habits” factor identified here. The prominent “appetitive drive” or “drive to overeat” factors revealed by both scales may demonstrate a tendency to overconsume despite negative consequences in those with high scores on the YFAS or AEBS. For example, the item “I eat to the point where I feel physically ill” in the YFAS and “I eat until I feel sick” in the AEBS both fall into this construct, and clearly represent similar features of overeating. The converging labels of the secondary factor across the two scales may highlight the prominence of items representing dietary control included in the AEBS (for example; “ Despite trying to eat healthily, I end up eating ‘naughty’ foods” and “I believe I have a healthy diet”). The items on the YFAS which loaded onto the “strength of food habits” factor, however, were more representative of the emotional consequences of overeating or attempting to reduce overconsumption (such as “Over time, I have found that I need to eat more and more to get the feeling I want, such as reduced negative emotions or increased pleasure”), rather than dietary control. Taken together, there is an evident importance of the drive to overconsume in individuals who are struggling with their food intake.

Given the elements of overeating, psychological impairment and addictive behaviours which the YFAS is argued to incorporate (Davis, Curtis, et al., 2011; Gearhardt, White, et al., 2012), it could be expected that the primary factor may be interpreted as reflecting overeating behaviours whilst the secondary factor might include those items in the YFAS measuring psychological impairment or addictive traits towards eating (withdrawal, tolerance, for example). However, no such clarity was identified in the present study. Moreover, neither factor seem to align coherently with any of the seven symptomatic criteria extracted from the DSM-IV-TR or ‘clinical impairment or distress as a result of overeating’ upon which the YFAS is based. Such results conclude that the underlying constructs of the YFAS appear not to be measuring any behaviours indicative of a possible ‘food addiction’ phenotype and further highlight the poor translation of the DSM-IV-TR criteria for substance dependence onto eating behaviour (Finlayson, 2017).

In addition, the final two-factor model of the YFAS confirmed by the CFA in this study contained only seven items: items 3, 5, 7 and 8 in Factor 1 and items 19, 20 and 21 in Factor 2. The importance of the remaining YFAS factors must therefore be questioned, given that these items contribute to the final ‘symptom count’ and ‘diagnostic’ scores of the YFAS, yet do not contribute to its underlying component structure. In particular, those items which were excluded from the PCA because of their weak psychometric properties are recommended to be excluded from the YFAS (items 24, 10, 11, 4 and 9). For example, Innamorati et al. (2015) and Meule, Heckel, and Kübler (2012) reference item 24 as being endorsed by the majority of participants and thus unable to discriminate between ‘food addicts’ and ‘non-food addicts’. Additionally, Innamorati et al. (2015), reported items 10 and 11 to be ‘problematic’, with corrected item total correlations of below .30 and no decrease in Cronbach’s alpha when deleted. These items seem not to contribute to any of the underlying factors of the YFAS.

3.5.1 Internal consistency of the underlying constructs

The internal reliability of the two identified underlying constructs of the YFAS were below the recommended minimum Cronbach’s α of .70 (Tavakol & Dennick, 2011), and only explained 35.15% of variance. Fundamentally, however, the concept of internal reliability assumes that the test is unidimensional (Miller, 1995; Tavakol & Dennick, 2011). As the present results have revealed a bi-dimensional structure of the YFAS, the assumption that the items are each measuring the same latent trait is violated and reliability for each of the underlying constructs may be underestimated. Nevertheless, some items in the present study revealed low inter-item correlations suggesting a weak internal reliability. It is recommended that items with the lowest inter-item correlations should be removed from the scale in order to improve Cronbach’s alpha (Ferketich, 1991). Those items not meeting the level of correlation displayed by the other items should be the first to be discarded, thus in the case of the present results, item six (r_{itc} = .19) would be a candidate for exclusion from the scale. As a whole, these results do not support the internal reliability of the YFAS or its underlying constructs.

3.5.2 Limitations

The obvious limitations of the present study lie in the reliability of self-reported data, a criticism often cited in debates surrounding the administration of the YFAS (Gearhardt, Boswell, et al., 2014; Innamorati et al., 2015; Meule & Gearhardt, 2014a). Furthermore, the focus on a University sample as a source of recruitment and a disproportionately large amount of females in both samples reduce the generalisability of these results. In addition, both samples did not screen for or exclude those with clinical disorders thus introducing more variance in YFAS scores, though this variance is likely to represent a more generalisable sample.

3.5.3 Conclusions

In summary, the results of the present study suggest the psychometric properties of the YFAS, the foremost tool for assessing FA may be quite weak and unstable. Whilst there is evidently a proportion of the population who meet one or more of the YFAS criteria and therefore are demonstrating problematic eating behaviours, these individuals cannot be concluded to be demonstrating a food ‘addiction’; but rather may demonstrate strong food habits and appetitive drive, possibly enhanced in response to highly palatable foods.

Although psychometric scales such as the YFAS are important tools to capture the specific eating behaviours that characterise individuals susceptible to overeating and weight gain, self-report questionnaire responses alone should not be used to quantify or measure a supposed clinical condition. Merely applying the criteria used to define substance-use disorders to overeating does not appear sufficient to capture the phenomenological features of an addiction to food and/or eating (Hebebrand et al., 2014; Ziauddeen et al., 2012b), especially given the weak psychometric properties and factor structure of the YFAS identified in this chapter. Despite this, both the concept of food addiction and its measurement using the YFAS are likely to persist, given that many individuals struggle with explaining food-related issues and overeating.

Summary

- Confirmatory Factor Analyses did not support a one-factor structure identified in previous literature or a seven-factor structure tested to represent seven of the criteria from the DSM upon which the YFAS is based.
- Subsequent exploratory factor analysis with Principal Components Analysis and Parallel Analysis revealed a two factor model of the YFAS which explained 35.15% of variance, though it was suggested that items 4, 9, 10, 11 and 24 should be removed from the scale.
- The fit of this model was confirmed in a Confirmatory Factor Analysis although two additional items with poor factor loadings were revealed (items 22 and 25).
- These two constructs explained 35.15% of variance, demonstrated low internal reliability (Cronbach’s α = .67 and .58 respectively) and did not seem to contain themes which reflected specific ‘addiction’-related behaviours towards overeating.
- The YFAS possessed weak psychometric properties and scores on this scale should be interpreted cautiously in research exploring FA as a clinical condition.

Chapter 4

An online survey of the Yale Food Addiction Scale: Is food addiction a singular and distinct entity from binge eating?

Aims

- To identify the prevalence of YFAS-diagnosed FA in a large sample of the UK population.
- To compare the strength and direction of the associations between the YFAS and the Binge Eating Scale (BES) with measures of problematic eating, addictive behaviour and psychological wellbeing.

4.1 Abstract

Background: It is frequently assumed in research deploying the Yale Food Addiction Scale (YFAS) that scores can be used to measure and 'diagnose' the presence of so-called 'food addiction'. However, the systematic review in Chapter 2 found that YFAS scores are frequently associated with binge eating, consistent with the idea that the YFAS scores may not be distinct or distinguishable from Binge Eating symptoms as can be measured by the Binge Eating Scale (BES). This therefore warrants investigation into whether the YFAS is able to identify any unique qualities beyond those already accounted for by the BES to support its status as a unique entity.

Method: A large cross-sectional study of male and female UK adults (N: 667, minimum age: 18, mean: 26.27, SD: 11.05) was conducted between April 2015 and March 2016. Participants completed thirteen psychometric scales, presented in a counterbalanced order, to assess problematic eating behaviours, psychological wellbeing and addictive behaviour traits.

Results: 7.65% of the sample met the YFAS criteria for 'food addiction' (N=51), the mean 'symptom count' was 1.88 (±1.45), and the mean 'sum-score' was 2.85 (±2.83). YFAS 'symptom count' correlated most strongly with the BES (r = .66). The BES correlated as strongly as the YFAS with all other measures of eating pathology, psychological distress and addictive behaviour traits. Subsequently, the YFAS 'symptom count' and BES were added simultaneously as predictors in multiple regression analyses. The results demonstrated that, when controlling for the BES, the YFAS was a significant predictor of scores on all variables except the Control of Eating Questionnaire Craving Savoury subscale and Eating Disorder Examination Restraint subscale. However, when controlling for the YFAS, the BES was a statistically significant predictor of all variables, including the CoEQ Craving Savoury subscale and EDE restraint subscale. Neither the YFAS nor the BES could significantly predict scores on the Drug Abuse Screening Test, despite vulnerability to drug abuse being a central concept of addiction.

Conclusion: These results suggest that the YFAS does not measure the proposed construct of FA, nor any traits which differ markedly from those measured by the BES. Small associations between the YFAS and traits central to addiction-related behaviours suggest that the YFAS may not be measuring 'addictive' eating. A clear definition of FA as a distinct condition from BES is needed before there can be any scientific basis for its validation.

4.2 Introduction

Despite the weaknesses and lack of agreement in the psychometric properties of the YFAS (as discussed in Chapter 3), it is frequently assumed that individuals' responses on the YFAS indicate a 'diagnosis' of a unique disorder, labelled 'food addiction' (FA). Much of this literature has focussed on the co-morbid behaviours which may be experienced by YFAS-diagnosed 'food addicts', including emotional eating, compulsive cravings, night eating and, in particular binge eating (this is debated in detail in Chapter 2). Regardless of these co-morbidities, few attempts have been made to define the specific behaviours which may characterise a 'food addict' and distinguish them from existing aberrant eating behaviours.

One proposed characteristic of so-called FA hones in on the substantial overlap between BED and food addiction, as described in Chapter 2, leading researchers to suggest that FA may be best understood as a "pathologically dense" (Davis, 2013a, p.171), "disturbed variant" (Gearhardt, White, et al., 2012; p.661) or "acute" version of Binge Eating Disorder (BED; Davis, 2013b; Gearhardt, White, & Potenza, 2011; Vainik, Neseliler, Konstabel, Fellows, & Dagher, 2015). This perspective is debated however (Avena, Gearhardt, et al., 2012; Cassin & von Ranson, 2007; Davis, 2016; Gearhardt, White, et al., 2011; Leigh & Morris, 2016; Ziauddeen et al., 2012a, 2012b), given that certain individuals meet the YFAS criteria for FA without endorsing a BED diagnosis, and vice-versa. This argument is often cited in favour of the distinctiveness of FA as a unique condition (Davis, 2016; Gearhardt, White, et al., 2011; Ivezaj, White, & Grilo, 2016).

As discussed in Chapter 1, certain clinical overlaps between BED and FA are to be expected, given the similarities in diagnostic constructs for these two conditions. For example, the 'substance taken in larger amounts than was intended' or 'persistent desire to cut down', criteria of the YFAS are directly applicable to binge eating behaviour (Smith & Robbins, 2013). There are, however, criteria included in the YFAS which do not seem to apply to a BED diagnosis, such as 'tolerance' and 'withdrawal' (Cassin & von Ranson, 2007); behaviours which are typical of substance-dependence (American Psychiatric Association, 2013).

One possible explanation for why FA and BE might be distinguishable could be differing levels of co-morbid substance abuse in these populations. For example, there is considerable evidence that individuals with eating disorders (anorexia nervosa; AN, bulimia nervosa; BN, and BED, for example) have high rates of drug use as well as more problematic and heavier use of these substances, whilst high levels of disordered eating in substance-dependent individuals are often reported (Avena et al., 2011; Holderness, Brooks-Gunn, & Warren, 1994; Ross & Ivis, 1999). On the other hand, the relationship between YFAS-defined food addiction and substance use is mixed, with some studies reporting an association between YFAS score and substance use (for example, Clark & Saules, 2013), and others reporting no association (Gearhardt, White, et al., 2012; Koball et al., 2016), as described in detail in Chapter 2. Perhaps those individuals who report a disposition towards overeating are less likely to report use of other substances as their preferred source of reward is specific to food, which is widely available and easily accessible. In a sample of 141 post weight loss surgery (WLS) adults, those meeting a pre-surgical diagnosis of food addiction were more likely to report problematic substance use post-surgery (Reslan et al., 2014). Similarly, in a study in middle-aged and older women, Flint et al. (2014) found that individuals who were defined as ‘food addicts’ were less likely to be current smokers, yet former smokers were more likely to meet current food addiction criteria. This argument would suggest that the BES should be able to predict scores on measures of alcohol or drug use better than the YFAS, yet the YFAS should better predict scores on measures of addictive personality better than the BES.

In addition, although associations between FA and, for example, negative emotional states and substance taking, have been documented (see Chapter 2), such overlaps are also common in BED and other eating disorder patients (for example: Peveler & Fairburn, 1990; Wilson, 1991, 2010), whilst one study even reported that the relationship between FA and psychopathology was fully accounted for by binge eating severity (Imperatori et al., 2014). Thus, to distinguish FA from BED as a distinct ‘addiction’ disorder, FA should display stronger relationships with these behaviours, compared to binge eating. Based on current knowledge, this is a relatively unexplored path of research and may uncover interesting insights into the pathological traits of a subgroup of individuals identified by the YFAS who display extreme loss of control over food consumption.

4.2.1 Objectives

The primary aim of the current chapter is to critically explore whether the YFAS is able to identify any unique correlates beyond those behaviours already associated with binge eating, as measured by the Binge Eating Scale (BES; Gormally, Black, Daston, & Rardin, 1982). To do this, the prevalence of YFAS-defined 'food addiction' in a diverse sample of the UK adult population is reported, followed by correlation analyses to compare the associations between both the YFAS and BES and psychometric measures of eating behaviour, addictive behaviour, alcohol and drug use and psychological wellbeing. In addition, multiple regression analyses aimed to compare the ability of the YFAS and BES in predicting scores on eating-related, addiction-related or psychological impairment.

It was hypothesised that: H_1) the YFAS should show stronger associations with measures of behaviours associated with 'addiction', particularly addictive behavioural traits, and psychological distress, compared to the BES.

4.3 Methods

A cross-sectional, survey-based, empirical investigation was conducted. A number of questionnaires were administered, including the YFAS, measuring a range of eating-related behaviours, consumption of alcohol and drugs, addictive behavioural traits and psychological wellbeing.

4.3.1 Participants

The survey was distributed using Qualtrics (Provo, Utah, USA, www.qualtrics.com). Responses were collected between April 2015 and March 2016. Male and female adult (minimum age 18) residents of the UK were recruited (N=1257). No other exclusion criteria were applied in order to gain a wide-ranging sample of the UK population. Only those providing full psychometric data to all questionnaires were included in the analyses (N=667).

Participants were recruited via the School of Psychology Participant Pool Scheme, whereby participation resulted in course credits. University e-mailing lists were utilised and social media, blogs, and forums were used to advertise the study website to a wider audience. The ability to enter a cash prize draw of £30 upon completion of the study was used as an incentive to take part. Ethical approval for the study was granted by the University of Leeds Institute of Psychological Sciences ethics committee.

4.3.2 Procedure

The recruitment advert provided a direct web link to the survey. After reading standardised instructions and consenting to take part in the survey, participants answered a demographic questionnaire, followed by thirteen psychometric assessments, including the YFAS, displayed to participants in a random order to reduce order effects. After completing the psychometric assessment, participants were shown a debrief and thanked for their time and participation. Participants were invited to provide their email address and postcode if they wish to be entered into the prize draw and/or contacted regarding future studies.

4.3.2.1 Psychometric Assessment

4.3.2.1.1 Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009b)

This 25-item instrument is based upon the symptom criteria for substance dependence according to the DSM-IV-TR and is described in detail in Chapter 1. For the present study, the dichotomous “diagnosis”, “symptom count” and “sum-score” were calculated.

4.3.2.1.2 Binge Eating Scale (BES; Gormally et al., 1982)

This 16-item questionnaire assesses the presence of certain binge eating behaviours which may be indicative of an eating disorder specifically in obese individuals. The questions are based upon both behavioural characteristics (e.g. amount of food consumed) and emotional or cognitive responses (e.g. guilt or shame). Each item is assigned a weight of 0 (no indications of binge eating) to 3 (severe binge eating manifestations), which are summed to create a total score (range 0 - 46). A score of <17 reflects little to no binge eating pathology, whilst a score of 18-26 displays moderate binging, and ≥27 severe binge eating pathology. The BES has been shown to have good internal consistency (α = .89; Freitas, Lopes, Appolinario, & Coutinho, 2006) and test-retest reliability (Timmerman, 1999).

4.3.2.1.3 Control of Eating Questionnaire (CoEQ; Dalton, Finlayson, Hill, & Blundell, 2015)

The CoEQ comprises 21-items designed to examine the strength and nature of an individual's food cravings the previous 7 days. Twenty items are assessed using 100-mm visual analogue scales (VAS) and one item (item 20) allows participants to specify their own selected food. The CoEQ has four subscales; Craving Control; Positive Mood; Craving for Savoury, and Craving for Sweet, with Cronbach's alpha values of .88, .74, .66 and .67, respectively (Dalton et al., 2015). The CoEQ has been successfully used in clinical weight-loss trials (Wadden et al., 2011) as a multi-dimensional measure of craving, appetite and mood regulation.

4.3.2.1.4 Three Factor Eating Questionnaire (disinhibition subscale, TFEQ-D; Stunkard & Messick, 1985)

The 16-item disinhibition subscale of the TFEQ was chosen as disinhibition has been found to reliably predict weight change (Bryant, Caudwell, Hopkins, King, & Blundell, 2012; Hays & Roberts, 2008), BMI (Bryant, King, & Blundell, 2008; Lawson et al., 1995; Riou et al., 2011) and impaired psychological well-being (Lattimore, Fisher, & Malinowski, 2011; V. Provencher et al., 2006). Responses are scored 0 or 1 and summed, whereby greater scores denote higher levels of disinhibited eating. High Cronbach's alpha scores have been reported for the disinhibition subscale (α = .91; Taboada et al., 2015).

4.3.2.1.5 Power of Food Scale (PFS; Cappelleri et al., 2009)

This 15-item instrument measures the appetitive aspects of eating, as opposed to the consummatory features commonly identified by other eating behaviour scales. As such, the PFS aims to access the possible feelings of being controlled by food, independent of actual food consumption. The items on the PFS are presented on a five-point Likert scale ranging from 1 ("do not agree at all") to 5 ("strongly agree"), whereby a higher score indicates a greater responsiveness to the food stimuli in the environment. The scale has high internal consistency (Cronbach's α = .91), adequate test-retest reliability and the three factors (food available, food present, and food tasted) are highly correlated (Lowe et al., 2009).

4.3.2.1.6 Eating Disorder Examination (restraint subscale, EDE-R; Christopher G. Fairburn & Beglin, 1994)

The restraint subscale of the EDE is a 5-item 7-point Likert scale ranging from 0 ("no days") to 6 ("every day"). The scores for each item are added together and the sum divided by the total number of items in the subscale, with higher scores indicating greater levels of symptomatology. Each item measures restraint over eating, avoidance of eating, food avoidance, dietary rules, and empty stomach respectively. The EDE retains high internal consistency in clinical (α = .70; Peterson et al., 2007) and community (α = .84-.85; Luce & Crowther, 1999; Mond, Hay, Rodgers, Owen, & Beumont, 2004) samples.

4.3.2.1.7 World Health Organisation Quality of Life Assessment (WHOQOL-BREF; Skevington, Lotfy, & O'Connell, 2004)

The WHOQOL-BREF is an abbreviated, 26-item version of the WHOQOL-100 (The WHOQOL Group, 1998). This 26-item instrument comprises four domains: Physical Health, Psychological, Social Relationships and Environmental. Items inquire 'how much', 'how completely', how often', 'how good' or 'how satisfied' participants felt in the last 2 weeks, and different response scales are distributed across the four domains. The four domains were found to have Cronbach's α scores of .82, .81, .68 and .80, respectively (Skevington et al., 2004).

4.3.2.1.8 Beck Depression Inventory (BDI; Beck, Steer, & Brown, 1996)

This 21-item inventory measures the severity of depression in adolescents and adults aged thirteen years or older according to the criteria for diagnosing depressive disorders in the DSM-IV. The subject is asked to consider a number of statements, each assessing a different symptom, and grade each one from 0 to 3 reflecting its level of severity. A total score of severity is calculated by summating the scores corresponding to the statements across the 21 items. In a review of 25 studies using the BDI, Beck, Steer, and Carbin (1988) reported that, in psychiatric populations, the coefficient alphas ranged from 0.76 to .95 with a mean α of .86 and in non-clinical samples the α ranged from .73 to .92 (mean α = .81).

4.3.2.1.9 Perceived Stress Scale (PSS; S. Cohen & Williamson, 1988)

The 10-item version of the PSS is designed to measure “the degree to which situations in one’s life are appraised as stressful” (S. Cohen, Kamarck, & Mermelstein, 1983, p. 385). The PSS-10 measures the extent to which the individual perceives their life as uncontrollable, unpredictable, and overloading, using a five point Likert scale. Scores range from zero to forty whereby a higher score indicates greater perceived stress. The PSS-10 has yielded an overall internal consistency value of α = .89 (Roberti, Harrington, & Storch, 2006). In the present experiment, the PSS-10 has been adapted to reflect perceived stress in the last two weeks, as opposed to the last month, in order to align with the WHOQOL-BREF.

4.3.2.1.10 State-Trait Anxiety Index (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983)

This 40-item self-report inventory differentiates between temporary “state anxiety” and long-term “trait anxiety” and distinguishes these conditions from depression. The instrument includes 20 items for assessing trait anxiety and 20 for state anxiety, all of which are rated on a 4-point Likert scale whereby a higher score indicates greater anxiety. Internal consistency (Cronbach’s alpha) for the trait and state scales are .90 and .92 respectively (Kabacoff, Segal, Hersen, & Van Hasselt, 1997).

4.3.2.1.11 Addiction-Prone Personality Scale (APP; Anderson, Barnes, & Murray, 2011)

The APP is a measure of personal vulnerability to Substance Use Disorders (SUDs). This 21-item scale has been found to predict alcohol dependence symptoms above and beyond the three most commonly administered personality scales: the Revised Eysenck Personality Questionnaire (EPQ-R;

Eysenck, Barrett, & Eysenck, 1984), the NEO Five Factor Inventory (FFI; Costa & McCrae, 1989), and the short form of the Temperament and Character Inventory (TCI; Cloninger, Przybeck, & Svrakic, 1994). The APP has demonstrated adequate internal consistency (α = .73), test–retest reliability (*r* = 74; Anderson et al., 2011).

4.3.2.1.12 Alcohol Use Disorder Identification Test (AUDIT; Fleming, Barry, & Macdonald, 1991)

The 10-item AUDIT was developed by the World Health Organisation (WHO) to screen for alcohol use disorders using the DSM-III criteria as the standard for diagnosis. Questions measure alcohol consumption, drinking behaviour, adverse reactions and alcohol-related problems (Saunders, Aasland, Babor, De La Fuente, & Grant, 1993). Each question is scored from 0 to 4 (range 0 - 40) and the WHO recommends a total score of 11 or more as suggestive of a drinking problem (Fleming et al., 1991). A high internal consistency of α = .80 was found in a sample of 989 undergraduate students (Fleming et al., 1991).

4.3.2.1.13 Drug Abuse Screening Test (DAST; Skinner, 1982)

The DAST is a 28-item self-report screening tool for identifying individuals who are abusing psychoactive drugs. A yes/no response is required for each of the 28 items, yielding a quantitative index indicating the extent of drug use. An internal consistency of .92 (Skinner, 1982) and .94 (Staley & el-Guebaly, 1990) have been reported, whilst 85% overall accuracy in classifying drug-abuse individuals according to DSM-III diagnosis was found by D. R. Gavin, Ross, and Skinner (1989).

4.3.3 Data analysis plan

Data was analysed using SPSS statistics (IBM Corp., Armonk, NY) version 22. Results are reported as Mean (±SD) unless otherwise specified. Associations between scores on all psychometric scales were explored using bivariate correlations. Subsequently, multiple linear regression was performed using the ‘enter’ method whereby the YFAS and BES were entered simultaneously as predictors of each of the other psychometric assessments in turn. For regression analyses alpha was set at $p<.05$. Bootstrapped confidence intervals (95%) were computed where appropriate using replacement sampling

(N=5000) from the dataset of the original sample size. Where zero is not in the 95% confidence interval, it was concluded that the indirect effect is significantly different from zero.

4.4 Results

4.4.1 Participant demographics

The mean age of the sample was 26.27 (±11.05), 82.20% were female (N=548) and 81.9% were White British (N=546). 7.65% of the sample met the YFAS criteria for ‘food addiction’ (N=51). Demographic information and scores on all trait measures for males and females are included in Appendix D.

Self-reported age, weight (kg), BMI and scores on all trait measures are presented in *Table 3* according to different samples (full sample, those meeting a YFAS “diagnosis” and those not meeting a YFAS “diagnosis”). Independent samples *t*-tests were conducted to compare scores on all domains between the YFAS “diagnosis” and no YFAS “diagnosis” groups. There was a significant difference between the YFAS “diagnosis” and no YFAS “diagnosis” groups in self-reported weight, BMI, YFAS ‘symptom count’, YFAS ‘sum-score’, BES, all CoEQ subscales, TFEQ-D, PFS, EDE-R, PSS, STAI State and Trait subscales, APP and AUDIT. There were no significant differences in age or DAST scores according to YFAS “diagnosis”. These results are reported in *Table 3*. Chi-square analyses revealed a significant difference in frequency distribution of gender in the FA and Non-FA groups (χ^2 (1) = 7.30, p <.01) whereby 81% (N=499) of the Non-FA group were female compared to 96.10% (N=49) in the FA group.

Table 3. Demographic statistics of the full sample, those meeting a YFAS "diagnosis" and those not meeting a YFAS "diagnosis"

Measure		Total sample (N=667)		YFAS "diagnosis" (N=51)		No YFAS "diagnosis" (N=616)		*t*-test
		Mean	SD	Mean	SD	Mean	SD	*t*
Age		26.24	11.05	23.78	9.68	26.48	11.14	1.68
Self-reported weight (kg)		65.71	15.72	72.36	21.08	65.16	15.08	-3.17**
BMI (kg/m^2)		23.22	5.01	25.98	7.06	22.99	4.74	-4.14***
YFAS 'symptom count'		1.88	1.45	4.75	1.28	1.64	1.18	-17.93***
YFAS 'sum-score'		2.85	2.83	9.22	3.62	2.33	2.00	-21.89***
BES		9.94	8.25	25.80	8.83	8.63	6.69	-17.15***
CoEQ	Craving Control	59.68	23.65	30.59	19.46	62.08	22.34	9.77***
	Craving Sweet	44.38	24.62	62.32	23.73	42.90	24.12	-5.53***
	Craving Savoury	46.01	21.49	55.83	19.96	45.20	21.42	-3.45**
	Positive Mood	61.13	17.03	49.39	14.27	62.10	16.88	5.22***
TFEQ Disinhibition		7.18	3.97	12.78	2.87	6.71	3.68	-11.49***
PFS		2.67	.89	3.58	.78	2.59	.86	-7.97***
EDE Restraint		1.32	1.29	2.85	1.40	1.19	1.19	-9.95***
QOL	Physical Health	16.15	2.35	14.14	2.51	16.32	2.26	6.56***

Measure		Total sample (N=667)		YFAS "diagnosis" (N=51)		No YFAS "diagnosis" (N=616)		*t*-test
		Mean	SD	Mean	SD	Mean	SD	*t*
	Psychological	14.13	2.78	11.02	2.86	14.39	2.62	8.78***
	Social Relationships	14.77	3.18	12.37	3.44	14.97	3.07	5.77***
	Environmental	15.66	2.01	14.32	2.35	15.77	1.94	5.03***
BDI		9.35	7.93	19.12	10.67	8.54	7.10	-9.78***
PSS		15.93	7.00	22.20	6.82	15.41	6.77	-6.87***
STAI	State	37.25	10.97	48.10	10.77	36.35	10.51	-7.66***
	Trait	41.25	11.97	54.18	10.44	40.18	11.46	-8.44***
APP		7.66	3.44	9.88	3.28	7.48	3.39	-4.88***
AUDIT		8.86	5.63	10.47	6.35	8.73	5.55	-2.13*
DAST		1.01	1.85	1.43	2.58	.97	1.77	-1.70

* $p < .05$, ** $p < .01$, *** $p < .001$

4.4.2 Endorsement rates of YFAS 'symptoms'

In order to examine the most common FA 'symptoms' reported by participants, endorsement rates of the YFAS 'symptoms' were examined. To explore whether those individuals meeting a YFAS "diagnosis" differ from those not meeting a YFAS "diagnosis" or from the full sample, endorsement rates were compared across these samples and are presented in *Table 4*. The "persistent desire or repeated unsuccessful efforts to cut down or control eating" criterion was indicated by almost all participants in the full sample (88.90%), the FA group (98%) and the non-FA group (88.10%; *Table 4*) indicating that this criteria has poor ability to distinguish between 'food addicts' and 'non-food addicts' according to the YFAS. Such results are supported by the findings in

Chapter 3, whereby all the items contributing to this criterion were excluded from the final underlying model of the YFAS.

Table 4. Endorsement rates of each of the 'symptom' criteria of the YFAS by the full sample, FA group and non-FA group

YFAS criteria	Total sample (N=667)		YFAS "diagnosis" (N=51)		No YFAS "diagnosis" (N=616)	
	N	%	N	%	N	%
Substance taken in larger amounts and for longer period than intended	70	10.50	26	51	44	7.10
Persistent desire or repeated unsuccessful attempts to quit	593	88.90	50	98	543	88.10
Much time/activity to obtain, use, recover	99	14.80	30	58.80	69	11.20
Important social, occupational, or recreational activities given up or reduced	67	10	26	51	41	6.70
Use continues despite knowledge of adverse consequences	183	27.40	42	82.40	141	22.90
Tolerance (marked increase in amount; marked decrease in effect)	157	23.50	34	66.70	123	20
Characteristic withdrawal symptoms; substance taken to relieve withdrawal	83	12.40	34	66.70	49	8
Use causes clinically significant impairment or distress	59	8.80	51	100	8	1.30

4.4.3 Further examination of YFAS and severe binge eating

As outlined in *Table 3*, those meeting a YFAS 'diagnosis' had a significantly higher score on the BES compared to those not meeting a YFAS 'diagnosis' (t (665) = -17.15, p < .001, d = 2.50). To further explore this relationship, participants were categorised by their BES score into 'severe binge eaters' (SBE; N=33; BES score ≥ 27) or 'low/non-binge eaters' (LNBE; N=634; BES score < 27), as described by Freitas et al. (2006). In the SBE group, 63.60% (N=21) met the dichotomous YFAS 'diagnosis' for FA, whilst 4.70% (N=30) of participants did in the LNBE group (*Table 5*). These results demonstrate that not all YFAS-defined 'food addicts' present severe binge eating symptomatology, just as not all severe binge eaters meet the YFAS criteria for FA.

Table 5. A comparison of YFAS 'symptom count' and 'sum-score' according to BES group

	'Severe binge eaters' (N=33)		'Low/non-binge eaters' (N=634)		*t*-test
	Mean	SD	Mean	SD	*t*
YFAS 'symptom count'	4.61	1.64	1.74	1.29	-12.31***
YFAS 'sum-score'	9.27	4.38	2.52	2.28	-15.60***
	Frequency (N)				
YFAS "diagnosis"	21		30		
No YFAS "diagnosis"	12		604		

* p < .05, ** p < .01, *** p < .001

Independent samples *t*-tests were conducted to compare scores on the YFAS 'symptom count' and 'sum score' in the SBE and LNBE groups. These results demonstrated that the SBE group scored significantly higher on the YFAS 'symptom count' and 'sum-score' compared to the LNBE group (*Table 5*). These results demonstrate that, whilst not all severe binge eaters meet the dichotomous criteria for FA according to the YFAS, their FA ‘symptomatology is clearly increased compared to low or non-binge eaters.

4.4.4 Associations between YFAS ‘symptom count’ and measures of eating behaviour, psychological wellbeing and addictive personality traits

In order to investigate the associations between YFAS ‘symptom count’ and psychometric measures of eating behaviour, psychological wellbeing and addictive behaviour traits, correlation analyses were conducted. As depicted in *Table 6*, YFAS ‘symptom count’ correlated significantly with all measures of eating behaviour, psychological wellbeing and addictive personality traits (all p <.01). As predicted, YFAS ‘symptom count’ was most strongly correlated with Binge Eating Scale score (r =.66, p =.001, 95% CI [.61, .71]; *Table 6*).

In response to this strong overlap between BES and YFAS ‘symptom count’, the associations between the BES and psychometric measures of eating behaviour, psychological wellbeing and addictive personality traits were examined. The BES also correlated significantly with all other psychometric scales and at a similar strength as the YFAS ‘symptom count’, suggesting that those traits which the YFAS supposedly measures may already be accounted for by the BES. As such, and in accordance with the *a priori* hypothesis, these variables were included as predictors in subsequent regression analyses to further investigate this relationship.

Table 6. Correlations between YFAS 'symptom count' and measures of eating behaviour, addictive traits and psychological wellbeing

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. YFAS Symptom Count	-	.66**	-.52**	.37**	.25**	-.34**	.57**	.44**	.33**	-.37**	-.45**	-.24**	-.27**	.50**	.41**	.39**	.44**	.29**	.20**	.13**
2. BES		-	-.61**	.35**	.30**	-.37**	.78**	.59**	.52**	-.33**	-.53**	-.23**	-.26**	.56**	.46**	.41**	.48**	.29**	.21**	.14**
3. CoEQ Craving Control			-	-.63**	-.46**	.25**	-.59**	-.59**	-.28**	.22**	.29**	.12**	.19**	-.29**	-.33**	-.27**	-.30**	-.17**	-.20**	-.14**
4. CoEQ Craving Sweet				-	.27**	-.16**	.37**	.38**	.15**	-.11**	-.16**	-.10*	-.15**	.16**	.21**	.17**	.21**	.03	-.01	.01
5. CoEQ Craving Savoury					-	-.15**	.34**	.42**	.07	-.17**	-.20**	-.07	-.13**	.23**	.26**	.19**	.23**	.20**	.28**	.16**
6. CoEQ Positive Mood						-	-.31**	-.22**	-.22**	.60**	.70**	.48**	.52**	-.63**	-.71**	-.71**	-.74**	-.36**	-.13**	-.10**
7. TFEQ Disinhibition							-	.61**	.42**	-.26**	-.43**	-.18**	-.23**	.41**	.39**	.36**	.41**	.22**	.22**	.13**
8. PFS								-	.25**	-.22**	-.28**	-.08	-.14**	.28**	.33**	.26**	.32**	.19**	.25**	.15**
9. EDE Restraint									-	-.16**	-.31**	-.14**	-.12**	.30**	.21**	.26**	.26**	.14**	.07	.02
10. QOL Physical Health										-	.66**	.42**	.56**	-.65**	-.57**	-.59**	-.63**	-.36**	-.11**	-.09*
11. QOL Psychological											-	.55**	.57**	-.80**	-.69**	-.69**	-.79**	-.47**	-.17**	-.15**
12. QOL Social Relationships												-	.46**	-.47**	-.42**	-.45**	-.49**	-.26**	-.07	-.04
13. QOL Environmental													-	-.48**	-.48**	-.52**	-.52**	-.32**	-.13**	-.08*
14. BDI														-	.67**	.65**	.75**	.48**	.17**	.15**
15. PSS															-	.71**	.76**	.40**	.26**	.18**
16. STAI State																-	.88**	.35**	.10**	.07
17. STAI Trait																	-	.45**	.17**	.12**
18. APP																		-	.38**	.34**
19. AUDIT																			-	.39**
20. DAST																				-

** significant at the p<.01 level (2-tailed).
YFAS = Yale Food Addiction Scale; BES = Binge Eating Scale; CoEQ = Control of Eating Questionnaire; TFEQ = Three Factor Eating Questionnaire; PFS = Power of Food Scale; EDE = Eating Disorder Examination; QOL = WHO Quality of Life Assessment; BDI = Beck's Depression Inventory; PSS = Perceived Stress Scale; STAI = State-Trait Anxiety Inventory; APP = Addition Prone Personality Scale; AUDIT = Alcohol Use Disorders Test; DAST = Drug Abuse Screening Test

4.4.5 Can the YFAS better predict measures of eating behaviour, psychological wellbeing and addictive personality compared to the BES?

In order to examine whether the YFAS is able to predict scores on eating behaviour, psychological wellbeing and addictive personality scales compared to, and when controlling for, the BES, multiple linear regression analyses were performed. YFAS 'symptom count' and BES were entered simultaneously as predictors of scores on measures of eating pathology, psychological impairment, addictive behaviour traits and alcohol and drug use. The indirect effects were tested using bootstrapped confidence intervals (95%), computed using replacement sampling (N=5000) from the dataset of the original sample size.

4.4.5.1 Can the YFAS better predict measures of eating behaviour compared to the BES?

As outlined in *Table 7*, when controlling for the BES, the YFAS was a significant predictor of scores on all variables except the Control of Eating Questionnaire Craving Savoury subscale and Eating Disorder Examination Restraint subscale (minimum $p < .01$). When controlling for the YFAS, the BES was a significant predictor of scores on all variables (all $p < .05$). Analysis of the bootstrapped confidence intervals did not affect the significance of the results. Therefore, the BES is able to explain everything which the YFAS can explain and more, whilst the YFAS cannot explain anything not already accounted for by the BES.

Table 7. Results from regression analyses when the YFAS 'symptom count' and BES are added simultaneously to predict scores on eating behaviour scales (N=667)

Variable		YFAS 'Symptom Count'						BES					
					Bootstrap coefficients						Bootstrap coefficients		
						95% CI						95% CI	
		B	S.E. *B*	β	S.E. *B*	Lower	Upper	*B*	S.E. *B*	β	S.E. *B*	Lower	Upper
CoEQ	Craving Control	-3.40	.66	**-.21*** **	.67	-4.71	-2.07	-1.35	.12	**-.47*** **	.12	-1.58	-1.12
	Craving Sweet	3.97	.81	**.23*** **	.88	2.23	5.68	.59	.14	**.20*** **	.16	.29	.91
	Craving Savoury	1.31	.73	**.09**	.76	-.17	2.84	.64	.13	**.25*** **	.13	.38	.90
	Positive Mood	-2.00	.56	**-.17*** **	.59	-3.17	-.85	-.52	.10	**-.25*** **	.10	-.71	-.33
TFEQ Disinhibition		.25	.09	**.09** **	.09	.09	.42	.34	.02	**.71*** **	.02	.31	.38
PFS		.06	.03	**.10* **	.03	.01	.11	.06	.01	**.52*** **	.00	.05	.07
EDE Restraint		-.03	.04	**-.03**	.05	-.12	.06	.08	.01	**.54*** **	.01	.07	.10

* $p < .05$, ** $p < .01$, *** $p < .001$

YFAS = Yale Food Addiction Scale; BES = Binge Eating Scale; CoEQ = Control of Eating Questionnaire; TFEQ = Three Factor Eating Questionnaire; PFS = Power of Food Scale; EDE = Eating Disorder Examination

4.4.5.2 Can the YFAS better predict measures of psychological wellbeing compared to the BES?

As demonstrated in *Table 8*, when controlling for the BES, the YFAS was a significant predictor of scores on all measures (minimum $p < .01$). Similarly, when controlling for the YFAS, the BES was a significant predictor of scores on all measures (minimum $p < .01$). Analysis of the bootstrapped confidence intervals did not affect the significance of the results.

Table 8. Results from regression analyses when the YFAS 'symptom count' and BES are added simultaneously to predict scores on psychological wellbeing scales (N=667)

Variable		YFAS 'Symptom Count'						BES					
					Bootstrap coefficients						Bootstrap coefficients		
						95% CI						95% CI	
		B	S.E. *B*	β	S.E. *B*	Lower	Upper	*B*	S.E. *B*	β	S.E. *B*	Lower	Upper
WHO QOL	Physical Health	-.44	.08	**-.27*** **	.09	-.61	-.26	-.04	.01	**-.15** **	.01	-.07	-.02
	Psychological	-.36	.08	**-.19*** **	.09	-.54	-.19	-.14	.02	**-.40*** **	.02	-.17	-.11
	Social Relationships	-.33	.11	**-.15** **	.12	-.55	-.10	-.05	.02	**-.13** **	.02	-.09	-.01
	Environmental	-.25	.07	**-.18*** **	.07	-.39	-.10	-.03	.01	**-.14** **	.01	-.06	-.01
BDI		1.29	.23	**.24*** **	.27	.77	1.84	.39	.04	**.41*** **	.05	.30	.48
PSS		.93	.22	**.19*** **	.22	.48	1.36	.28	.04	**.33*** **	.04	.21	.36
STAI	State	1.56	.35	**.21*** **	.36	.86	2.29	.37	.06	**.28*** **	.07	.24	.49
	Trait	1.72	.37	**.21*** **	.37	1.00	2.46	.50	.07	**.34*** **	.07	.37	.63

* $p < .05$, ** $p < .01$, *** $p < .001$

YFAS = Yale Food Addiction Scale; BES = Binge Eating Scale; WHO QOL = WHO Quality of Life Assessment; BDI = Beck's Depression Inventory; PSS = Perceived Stress Scale; STAI = State-Trait Anxiety Inventory

4.4.5.3 Can the YFAS better predict measures of ‘addictive’ behaviours and alcohol and drug use compared to the BES?

Table 9 reveals that, when controlling for the BES, the YFAS was a significant predictor of scores on the APP, and when controlling for the YFAS, the BES was also a significant predictor of APP scores (minimum $p < .01$). In terms of alcohol use, both the YFAS and the BES (when controlling for the other) were significant predictors of scores on the AUDIT (minimum $p < .05$). With regards to drug use, neither the YFAS nor the BES were significant predictors of scores on the DAST, when controlling for one another. Analysis of the bootstrapped confidence intervals did not affect the significance of the results.

Table 9. Results from regression analyses when the YFAS 'symptom count' and BES are added simultaneously to predict scores on addictive behaviour scales (N=667)

Variable	YFAS 'Symptom Count'						BES					
				Bootstrap coefficients						Bootstrap coefficients		
					95% CI						95% CI	
	B	S.E. *B*	β	S.E. *B*	Lower	Upper	*B*	S.E. *B*	β	S.E. *B*	Lower	Upper
APP	.39	.12	**.16****	.12	.16	.63	.08	.02	**.19*****	.02	.04	.12
AUDIT	.43	.20	**.11***	.21	.01	.84	.09	.04	**.14****	.04	.02	.17
DAST	.09	.07	.07	.06	-.04	.22	.02	.01	.09	.01	0	.05

* $p < .05$, ** $p < .01$, *** $p < .001$

YFAS = Yale Food Addiction Scale; BES = Binge Eating Scale; APP = Addition Prone Personality Scale; AUDIT = Alcohol Use Disorders Test; DAST = Drug Abuse Screening Test

4.5 Discussion

The present study tested the proposition that food addiction is a distinguishable construct from binge eating by examining the ability of the YFAS to identify unique traits of overeating, addiction and psychological wellbeing beyond those already associated with binge eating, as measured by the Binge Eating Scale.

The results of this study identified a prevalence of FA according to the YFAS in a large sample of UK adults comparable to those reported in previous literature (for example, Brunault et al., 2014; Mason et al., 2013; Mason et al., 2014). However, demonstrating prevalence estimates should not be confused with generating evidence for the validity or existence of an unconfirmed condition.

Of particular interest is the ‘persistent desire or repeated unsuccessful attempts to quit’ criterion which was endorsed by all but one of the individuals who met the YFAS criteria for food addiction in the present sample. Similar endorsement rates have been found in obese samples (Brunault et al., 2016; Leigh & Morris, 2016; Meule, Heckel, & Kübler, 2012). However, Innamorati et al. (2015) reported weak psychometric properties of the items contributing to this criterion, being unable to discriminate between YFAS-defined food addicts and non-food addicts. Similar results were reported in Chapter 3, whereby all four of the items accounting for this criterion were excluded from the final model best fitting the data.

Analysis of the demographic statistics in the present sample revealed that those individuals who met the YFAS criteria for FA reported a higher weight and BMI, had greater levels of binge eating, craving for sweet and savoury foods, disinhibition, responsiveness to environmental food stimuli and restraint as well as lower craving control and a lower mood, compared to the non-FA group. In terms of psychological wellbeing, the FA group had a lower quality of life, a greater tendency towards depression, and higher perceived stress and anxiety. Additionally, the FA group had significantly higher scores on measures of addictive personality and alcohol use, but not on the measure of drug abuse.

Such findings were supported by statistically significant associations between the YFAS ‘symptom count’ and other measures of maladaptive eating behaviours, addictive behaviours, alcohol and drug use and psychological distress frequently described in the literature, demonstrating a relationship between YFAS-defined FA and these traits (Boggiano et al., 2014; Burgess et al., 2014; Clark & Saules, 2013; Davis, 2013a; Davis, Curtis, et al., 2011; Gearhardt, White, et al., 2012; Imperatori et al., 2014). However, such impairments to eating behaviour and quality of life are common to other EDs, including binge eating disorder (Cooper & Fairburn, 1987; de Zwaan et al., 1994; Specker, de Zwaan, Raymond, & Mitchell, 1994; Wilfley et al., 2000), thus cannot be used to justify the need for a new clinical entity.

Of particular importance is the very high correlation between the YFAS and BES (r =.66), raising further queries over whether the YFAS is conceptually different to binge eating (Davis, 2016; Ziauddeen & Fletcher, 2013). Furthermore, the BES correlated as strongly as the YFAS with all measures of eating pathology, addictive personality and psychological wellbeing. However, in all cases except the CoEQ Craving Sweet subscale and WHO Quality of Life Physical Health, Social Relationships and Environmental subscales, a stronger correlation between the BES and these variables was revealed, compared with the YFAS. Such results suggest that the YFAS reveals few traits which differ markedly from those measured by the BES. Such results are consistent with the suggestion that there may be an underlying trait of overeating behaviour, proposed by Vainik et al. (2015), labelled “uncontrolled eating”.

Moreover, a greater proportion of YFAS-defined ‘food addicts’ displayed ‘severe’ binge eating tendencies, compared to ‘non-food addicts’, whilst a higher proportion of ‘severe binge eaters’ met the YFAS ‘diagnosis’ for FA, compared to ‘low/non-binge eaters’. Such results are consistent with previous literature (for example; Clark & Saules, 2013; Gearhardt, Boswell, et al., 2014; Gearhardt et al., 2009b) and are expected given the high correlation between the YFAS and BES in this study. However, as described by Davis (2016), not all ‘food addicts’ display binge eating behaviours according to the YFAS, and vice-versa. In the present study, 36.40% of ‘severe binge eaters’ did not meet a dichotomous YFAS ‘diagnosis’ whilst 58.80% of YFAS-defined ‘food addicts’ did not display ‘severe’ binge eating tendencies. These results demonstrate that, though there may be similarities in some of the less extreme symptoms associated with binge eating and FA, it must not be assumed that the two are synonymous, nor that the YFAS is a comparable diagnostic tool to the BES.

These results were further supported by regression analyses whereby the YFAS ‘symptom count’ and BES were added simultaneously as predictors. When controlling for the BES, the YFAS was a significant predictor of scores on all variables except the Control of Eating Questionnaire Craving Savoury subscale and Eating Disorder Examination Restraint subscale. However, when controlling for the YFAS, the BES was a statistically significant predictor of all variables, including the CoEQ Craving Savoury subscale and EDE restraint subscale. Therefore, the BES can explain everything the YFAS can explain and more, while the YFAS cannot explain anything extra not already accounted for by the BES. Interestingly, both the YFAS and the BES could significantly predict scores on the AUDIT, consistent with the aforementioned findings that binge eating overlaps with alcohol and drug use, yet neither the YFAS nor the BES could significantly predict scores on the DAST. These findings demonstrate that those behaviours proposed to be central to an ‘addiction’, such as psychological impairment and addiction-prone personality, are already adequately explained by the clinically validated BES. This suggests that whilst the YFAS may appear to identify a small group of individuals reporting overeating and impaired psychological health, such behaviours are not significantly different to those which are identifiable by trait binge eating, and the YFAS may simply identify individuals with heightened responses to certain palatable foods.

4.5.1 Limitations

Whilst the present chapter identified and attempted to satisfy a major gap in the literature of FA regarding the lack of defining characteristics of this proposed condition, certain limitations of the present study exist. The study used self-reported, cross-sectional data, a criticism which is unavoidable given the questionnaire-based nature of the YFAS. However, this self-report design permitted collection of a large sample, allowing greater generalisability to the general population of the UK. Second, as the sample was intended to be representative of the general population, those with clinical disorders were not excluded from the study, thus likely introducing a greater amount of variance in scores on the psychometric scales. Third, a disproportionately large amount of females in the present study limits the generalisability of the results to males. Replication of the present analyses in a large male sample would improve future research, although binge eating is also overrepresented by females (Striegel-Moore & Cachelin, 1999), thus the present results maintain relevance. Finally, the length and intensity of the present study could have led to a reduction in response quality (Galesic & Bosnjak, 2009), though counterbalancing the order of the questionnaires and the large sample size aimed to overcome this limitation.

Such limitations highlight the urgent need for research concerning the YFAS and the proposed construct of FA to extend beyond cross-sectional, self-report measures and onto precisely controlled studies which objectively investigate food intake. To date, this type of behavioural research is broadly limited to animal studies (as discussed in Chapter 1) and currently only 3 studies have investigated the associations between YFAS-defined food addiction and actual food intake in humans (Chapter 2).

4.5.2 Conclusions

Taken together, whilst the YFAS may appear to identify a small group of individuals reporting overeating and impaired wellbeing, such behaviours are not significantly different to those already identified by existing overeating disorder characteristics, particularly trait binge eating. It can be argued that ‘food addiction’ is simply another label assigned to the multi-faceted array of behaviours associated with overeating, and that the use of this term does not verify that the construct of “food addiction”, “addictive-like eating” (Schulte, Grilo, & Gearhardt, 2016), or “eating addiction” (Hebebrand et al., 2014) exists. A new clinical condition should contribute novel information and understanding to help explain and treat pathology, and not overlap strongly with existing perspectives and conditions (C. G. Long, Blundell, & Finlayson, 2015). It seems that the issue at hand is one of semantics, whereby emotive language is used to describe food habits (Blundell et al., 2014) and various labels are assigned to (over-) eating behaviour. Indeed, it has been proposed by Vainik et al. (2015) that many common eating-related behaviours can be captured by a single factor with varying severity, labelled ‘uncontrolled eating' (p. 229). Applying a label of ‘food addiction’ or ‘addictive-like eating’ to this wealth of overeating behaviours, especially without a comprehensive theoretical basis for this proposed condition, lacks convincing support, and further trivialises serious addictions (Rogers & Smit, 2000).

Summary

- The prevalence of YFAS-diagnosed ‘food addiction’ of 7.65% was identified in the present sample, comparable to that reported in previous literature.
- The YFAS correlated weakly but significantly with measures of maladaptive eating behaviours, addictive behaviour traits and psychological impairment.
- The BES also correlated significantly with these measures, suggesting that the YFAS does not identify any constructs distinguishable from binge eating.
- Regression analyses further revealed that all measures which the YFAS could significantly predict were also predicted by the BES, suggesting any behaviours allegedly identified by the YFAS do not appear to be distinct from binge eating.

Chapter 5

An examination of the perceptions of foods varying in nutritional composition, energy density and palatability in YFAS-diagnosed "food addicts"

Aims

- To objectively identify which food attributes or nutrients are most strongly associated with individuals' perceptions of problematic eating behaviours and 'addictive' potential.
- To explore whether these perceptions differ according to the 'diagnosis' of 'food addiction', as measured by the YFAS.

5.1 Abstract

Background: A key proposition underpinning the concept of food addiction (FA) concerns the identification of specific foods or ingredients that might precipitate or maintain 'addiction-like' eating behaviour. A plethora of foods, including those high in carbohydrate and fat, or a combination of "highly processed" nutrients have been speculated to induce behaviours comparable to substance dependence. However, human evidence to support these claims is lacking. The present study therefore aimed to explore whether specific nutrients are most strongly associated with subjective perceptions of either 'problematic' or 'addictive' eating behaviours, and whether these perceptions differ in individuals categorised by the Yale Food Addiction Scale (YFAS) as 'food addicts' (FA group), compared to those not meeting the YFAS criteria (Non-FA group).

Method: Via an online survey, participants (N: 929, 86.50% female, age range 18-65, mean: 29.63, SD: 11.94) rated 25 singular food images on their perceptions of each food's 'associated problems' and 'addictive potential', followed by the completion of the YFAS. Independent samples *t*-tests and chi square analyses were used to compare the FA and Non-FA groups on demographic variables. Correlation analyses were utilised to identify which objectively measured food attributes and ingredients were most strongly associated with 'problematic' and 'addictive' ratings. Finally, hierarchical multiple regression analyses were conducted to explore whether any food attributes differentially predicted ratings of 'associated problems' and 'addictive' potential in the FA and Non-FA groups.

Results: 10.3% of the sample met the YFAS criteria for 'food addiction'. The FA group were significantly older and had a significantly greater number of current dieters (both $p \leq .05$) compared to the Non-FA group, therefore these variables were controlled for in subsequent regression analyses. Correlation analyses revealed that the strongest association between food attributes and perceptions of problematic eating and addictive eating behaviour was energy density (r =.60 and r =.66, respectively, both $p \leq .001$). Regression analyses were consistent with these results, revealing that foods higher in energy density were associated with greater ratings of perceived problems and addictive potential. Moreover, these predictors did not differ between the FA and Non-FA groups, despite the FA group reporting a greater tendency to rate foods as problematic or having addictive potential in general, compared to the Non-FA group.

Conclusions: These results demonstrate that a high score on the YFAS does not differentiate individuals who perceive certain foods as problematic or 'addictive' from those with lower scores. Energy dense foods are widely perceived to carry a greater potential for problematic or 'addictive' eating behaviours (in all subjects). Nutritional attributes that have been proposed as addictive substances such as 'sugar' and 'food processing' were not linked with addictive potential or problematic eating.

5.2 Introduction

A key proposition underpinning the concept of food addiction is that certain food constituents, particularly sugar or fat, may produce behavioural alterations of a similar severity to those produced by psychoactive drugs (Avena et al., 2011; Hone-Blanchet & Fecteau, 2014; Ifland et al., 2009; Volkow & Wise, 2005), although this view is debated (Finlayson, 2017; Ziauddeen et al., 2012b). Foods containing high levels of carbohydrate and fat have been labelled as “highly processed” (Gearhardt, Davis, et al., 2011; Polk, Schulte, Furman, & Gearhardt, 2016; Schulte et al., 2015) or “hyperpalatable” (Gearhardt, Davis, et al., 2011; Gearhardt, Grilo, DiLeone, Brownell, & Potenza, 2011), though these labels are poorly defined. It seems that an unspecified number of foods and ingredients in the modern environment are candidates for being defined as “addictive substances” (Schulte et al., 2015), including salt (Zhang & Kelley, 2002), potatoes (Ifland et al., 2009) and even carrots (Černý & Černý, 1992).

Much of the evidence in favour of the possible ‘addictive’ properties of carbohydrates and fat relies on animal studies. By inducing highly constrained or intermittent feeding regimes of high fat or high carbohydrate diets, researchers have succeeded in producing behaviours alleged to be indicative of substance dependence; including bingeing, withdrawal and tolerance, as discussed in Chapter 1 (Avena, Bocarsly, et al., 2012; Avena et al., 2008; Bocarsly, Berner, Hoebel, & Avena, 2011; Kanarek, D’anci, Jurdak, & Mathes, 2009). For example, rats will endure aversive environments such as foot shock in order to obtain a high fat food (Avena, 2010; Teegarden & Bale, 2007), whilst behaviours characteristic of withdrawal, such as anxiety and stress, are documented when these animals are removed from a high fat or high sucrose diet and subjected to a simple chow diet (Iemolo et al., 2012; Mathes, Ferrara, & Rowland, 2008). These behavioural adaptations are accompanied by neurological alterations, particularly in reward-related brain regions. For example, rats fed with a highly palatable cafeteria-style diet gained significantly more weight than those fed with a restricted access chow-only diet and this was accompanied by lower striatal DA receptor density (P. M. Johnson & Kenny, 2010). Additionally, increased concentrations of dopamine (DA) in the nucleus accumbens (NAcc) are demonstrated following sugar bingeing (Rada et al., 2005), an effect which persists using sham-feeding models, suggesting that the sweet taste of sucrose alone is sufficient to prompt DA-stimulated reward (Hajnal & Norgren, 2001; Hajnal, Smith, & Norgren, 2004). Similarly, sham feeding rodents with a high fat diet increased the release of striatal DA (Liang, Hajnal, & Norgren, 2006), an effect which could be blocked by a DA-receptor antagonist (Volkow, Wang, & Baler, 2011).

However, whilst animal models offer some support the presence of behaviours characteristic of 'addiction' following various dietary manipulations, and apparent similarities in brain activation can be demonstrated in humans, behavioural adaptations in humans indicative of an 'addiction' are yet to be reliably established (Benton, 2010; Ziauddeen & Fletcher, 2013). Instead, individuals who may be susceptible to developing 'addictive'-like eating behaviours are characterised according to the Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009b). The YFAS applies the criteria for substance dependence outlined in the Diagnostic and Statistical Manual (DSM-IV-TR; American Psychiatric Association, 2000) to the consumption of highly palatable foods, as described in Chapter 1. Correspondingly, individuals scoring highly on the YFAS describe consuming high fat and energy dense foods more frequently (Pursey, Collins, Stanwell, & Burrows, 2015) and consume a greater percentage of energy from confectionary, savoury packaged snacks and takeaway foods than other types of foods (Pursey, Stanwell, Collins, & Burrows, 2014). Similarly, Pedram et al. (2013) reported a greater dietary intake from fat in individuals meeting the YFAS criteria for FA, whilst intakes of fat and sugar were found to be elevated in YFAS-defined 'food addicts' in an obese population (Pedram & Sun, 2014).

These results suggest a greater preference for high fat or carbohydrate foods with increasing YFAS score. One possible explanation for this association could be attributed to individuals' subjective perceptions of foods. Food perceptions have been reported to influence energy intake, food selection and weight gain (Buckland, Dalton, et al., 2015; Capaldi, Owens, & Privitera, 2006; Oakes, 2005; Steptoe, Pollard, & Wardle, 1995). This has led food perceptions to be investigated in relation to YFAS score. For example, Schulte et al. (2015), investigated the role of fat content and glycaemic load (GL) in individuals' perceptions of 'problematic' eating behaviour towards an array of 35 foods. The results suggested that foods higher in fat and GL were most strongly associated with 'addictive'-like eating behaviours and problematic food ratings.

Furthermore, YFAS 'symptom count' was a small but positive predictor of these associations. Similarly, in a recent paper by Markus, Rogers, Brouns, and Schepers (2017), reports of problematic eating behaviours associated with high fat sweet and high fat savoury foods were more prevalent in those who met the YFAS criteria for FA. Although these results suggest a disposition towards perceiving high fat or carbohydrate foods as 'problematic' in high YFAS-scoring individuals, these studies did not include any objective nutritional information about the foods included in the studies. Rather, in the paper by Schulte et al. (2015), the foods were dichotomised into two groups according to whether or not the authors considered them to be "processed", as quantified by the subjective interpretations of the level of fat and/or refined carbohydrate in each food. Similarly, Markus et al. (2017) subjectively categorised the foods included in their methodology as sugar rich, high fat sweet/savoury or low fat savoury.

In light of this, an objective analysis of whether any specific subjective perceptions or nutritional attributes are implicated in individuals' perceptions of what constitutes a food with 'addictive' properties, particularly in those who identify as 'food addicts', is warranted.

5.2.1 Objectives

Using a novel platform for methodically assessing individual perceptions of foods' sensory characteristics, coupled with objective data on the foods' macronutrient composition (Buckland, Dalton, et al., 2015; Buckland, Stubbs, & Finlayson, 2015), the aims of this study were two-fold: 1) to identify which food attributes are most strongly associated with perceptions of 'addictive' or problematic eating behaviours; 2) to investigate whether YFAS-defined 'food addicts' differ from 'non-food addicts' in their perception of the attributes of different foods.

It was hypothesised (H_1) that fat and carbohydrate content (or a combination of these nutrients) will be most strongly associated with perceptions of problematic or addictive eating behaviours; and (H_2) that YFAS-defined 'food addicts' will be more likely to perceive high fat and high carbohydrate foods as 'problematic' (compared to low YFAS scorers) and consider them as more likely to possess 'addictive potential'.

5.3 Methods

A cross-sectional, survey-based study was conducted to examine subjective perceptions of foods as a function of objective food characteristics and YFAS score for a range of foods

5.3.1 Participants

The survey was distributed using Qualtrics (Provo, Utah, USA, www.qualtrics.com). Responses were collected between December 2015 and February 2016. Male and female adult (aged 18-65) residents of the UK were recruited (N=1796). Those taking medication or supplements known to affect appetite were excluded from the study, as were those with known allergies or intolerances to the study foods. Only those providing full psychometric information were included in the analyses resulting in a final sample size of 929, of which 86.50% of the sample were female.

Participants were recruited via the School of Psychology Participant Pool Scheme, whereby participation resulted in course credits. University e-mailing lists were utilised and social media, blogs, and forums were used to advertise the study website to a wider audience. The ability to enter a cash prize draw of £30 upon completion of the study was used as an additional incentive to take part. Ethical approval for the study was granted by the University of Leeds School of Psychology ethics committee.

5.3.2 Procedure

The recruitment advert presented a direct web link to the survey. After reading standardised instructions and consenting to take part in the survey, participants indicated their age, gender, ethnicity, self-reported height and weight, educational qualifications, general health status, diet status, general wellbeing and state hunger. Participants were also asked whether they considered themselves to be “addicted” to any food(s) or food ingredients and, if so, to define which specific food(s) or ingredient(s) they perceived themselves to be “addicted” to.

The motivational state of the participant was assessed by collecting information on the time since participants last ate (hours and minutes) and obtaining a rating of hunger (‘‘How hungry do you feel right now?’’) using a 7-point rating scale (1 = ‘not at all hungry’ to 7 = ‘extremely hungry’). This was followed by twenty-five images of foods commonly found in the diet and 7 questions relating to each food, using the ‘food perceptions platform’, as described below. Self-report measures of ‘food addiction’ (according to the YFAS) and health consciousness were subsequently assessed in a randomised order, although the measure of health consciousness will not be included in the present analyses. Participants were finally shown a debrief and thanked for their time and participation. Participants were invited to provide their email address and postcode if they wished to be entered into the prize draw and/or contacted regarding future studies.

5.3.3 Food perceptions platform

In order to assess participants’ perceptions of foods, a database of standardised photographic images (which includes over 300 potential foods images) was utilised, as described in previous studies conducted in our laboratory (Buckland, Dalton, et al., 2015; Buckland, Stubbs, et al., 2015). Foods were sourced from UK supermarkets and were prepared, weighed (to the nearest 0.1g) and photographed by researchers at the Human Appetite Research Group, University of Leeds, Leeds, UK, according to standardised operating procedures.

Foods were displayed to depict a typical serving size. Foods were presented on a plain white plate of 21.5 cm circumference or, if the food is typically consumed from a bowl, a glass bowl (circumference: 15.5 cm, height: 6 cm) was placed in the centre of the plate to ensure consistency between images (*Figure 8*).

Foods were photographed under laboratory-controlled conditions to ensure consistency in light exposure, background, and image quality. A Sony NEX-F3 camera was used to photograph the foods in colour and all images were edited to standardise image brightness, background and size (1024 x 768 pixels) using iPhoto (Apple Inc., California, USA). Only single food items were presented, to ensure that participants were able to correctly identify the displayed food, and in the absence of branding or packaging. Beverages were excluded due to difficulties in identifying beverages in the absence of their packaging. To ensure recognisability, energy, weight and macronutrient content varied between images to depict an appropriate serving size for each individual food.

For all foods in the database, nutritional information and cost (excluding promotional offers) was sourced from McCance and Widdowson's The Composition of Foods, 7th ed. (Finglas et al., 2014) or manufacturers' labelling. From the database, a final selection of 70 foods commonly found in the UK diet were included in the present study. The foods were selected according to five criteria: those which are commonly recognised in the diet; those included in the recent study by Schulte et al. (2015); those listed in the YFAS as example foods which "individuals sometimes have difficulty controlling their intake of" (Gearhardt et al., 2009b); those identified in a previous study in our laboratory which participants reported having difficulty in controlling their intake of; those included in the 2008 International Tables of Glycaemic Index and Glycaemic Load Values (Atkinson, Foster-Powell, & Brand-Miller, 2008). The included foods were cross-referenced against the UK Department of Health's Eatwell Plate (UK Department of Health, 2015) to ensure adherence to the recommended representation across the main food groups. The final foods varied in nutritional composition (kcal, energy density (kcal/gram) protein, carbohydrate, sugar, fat, fibre, salt) and cost (*Figure 8*).

From the final 70 food images, each participant was shown a pseudo-randomly selected sub-sample of 25 foods to avoid fatigue. The sub-sample of 25 foods was randomly selected by the survey tool, but if the participant reported any food allergies, intolerances or avoidance (due to dietary, ethical or religious reasons, for example) any non-complying foods would not be shown. A list of the foods included in the perceptions platform for the present study is presented in Appendix E.

Participants were asked to name each food to ensure that participants correctly recognised and rated the food presented (Buckland, Dalton, et al., 2015). For any incorrectly labelled foods their corresponding ratings were excluded (Buckland, Stubbs, et al., 2015). Each food item was presented individually on screen followed by 7 questions measuring participants' subjective perceptions of each food.

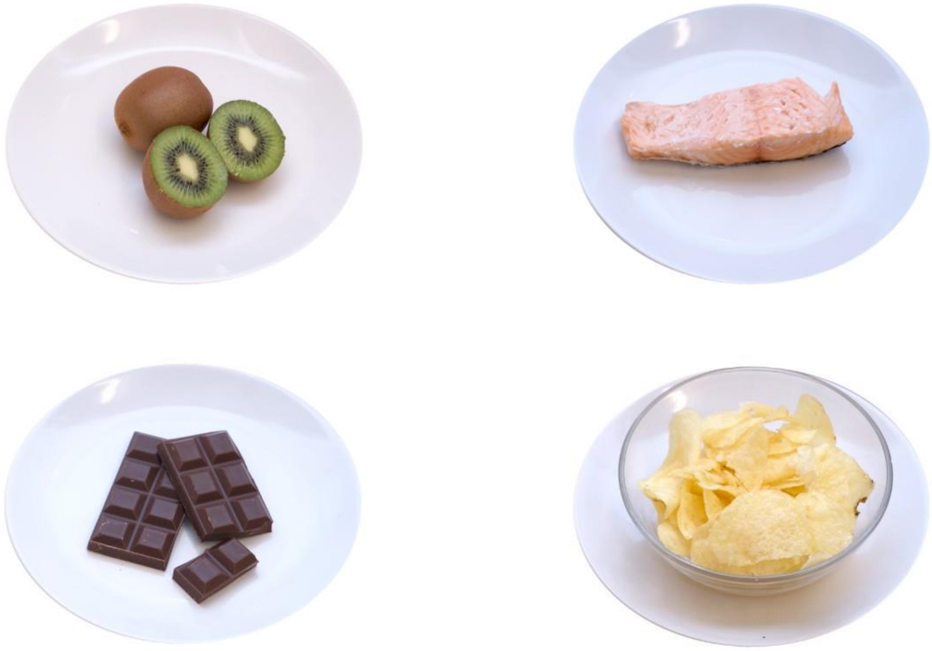

Figure 8. Examples of foods included in the database. From top left; kiwi, salmon fillet, chocolate, crisps

5.3.3.1 Measurement of participants' subjective perceptions

Using seven-point Likert scales, participants rated each food based on their subjective perception of its healthiness, how likely they are to experience 'problems' with it, its 'addictive potential', how much they like it, how often they crave it, its energy content and its satiating capacity. Each item and its response scale is described in *Table 10*. For the purpose of this chapter, only ratings of associated 'problems' and 'addictive potential' were used and, henceforth, 'subjective attributes' refers to participants' subjective ratings of foods based on their responses to these questions.

Table 10. The subjective attributes assessed and their associated items and response scales

Subjective attribute	Question	Response scale
Healthiness	To what extent do you think this food is healthy?	1 = not at all healthy 7 = extremely healthy
Associated problems	How likely are you to experience ‘problems’ with this food?	1 = not at all likely 7 = extremely likely
Addictive potential	To what extent do you believe this food has ‘addictive potential’?	1 = a very small extent 7 = a very large extent
Liking	Generally, how much do you like this food?	1 = not at all 7 = very much
Craving	Over the past week, how much have you craved this food?	1 = never 7 = extremely often
Energy content	Is this food low or high in calories?	1 = low calorie 7 = high calorie
Satiating capacity	Generally, how filling do you consider this food to be?	1 = not at all filling 7 = extremely filling

These questions were selected according to previous literature. The question regarding subjective ‘problems’ which participants might experience with each food was a direct extrapolation from Study 1 by Schulte et al. (2015), in order to allow direct comparisons between results. For this measurement, a definition was provided in the survey to ensure understanding and accurate ratings across participants. The following definition was given: *“An example of what we mean by ‘problems’ is having trouble cutting down on the food or losing control over how much of the food you eat. An example of what we do not mean by ‘problems’ is feeling like you aren’t eating enough of the food”*. This definition was derived from Schulte et al. (2015, p.6).

Assessing participants' perceptions of whether certain foods possess 'addictive potential' aims to address whether the proposition that certain foods can possess an "addictive" or "abuse" potential akin to psychoactive drugs is endorsed by the general population. Previous research which has utilised this label has provided weak attempts to precisely define this term. As such, in the present study the following definition was given: *"An example of what we mean by 'addictive potential' is the ability of this food to induce withdrawal symptoms when you do not or cannot eat the food or clinically significant impairment or distress associated with eating the food"*. This definition was developed for the purpose of this study and was intended to represent a definition of 'addictive potential' based on the DSM-IV-TR criteria for substance dependence, i.e., encompassing the 'withdrawal' and 'psychological distress' criteria (American Psychiatric Association, 2000).

5.3.4 Measurement of 'food addiction'

In order to measure self-reported 'food addiction', the Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009b) was utilised. This scale is described in detail in Chapter 1.

5.3.5 Data analysis plan

All statistical analyses were performed using IBM SPSS for windows (Chicago, Illinois, USA; Version 22). Data are expressed as mean ± SD unless otherwise stated. Where Levene's Test for Equality of Variances is statistically significant, equal variances were not assumed and results were adjusted accordingly. Bootstrapped confidence intervals (95%) were computed where appropriate, using replacement sampling (N=5000) from the dataset of the original sample size. Where zero is not in the 95% confidence interval, it was concluded that the indirect effect is significantly different from zero. Effect sizes were calculated using Cohen's *d*, whereby the values for small, medium and large effects, respectively, are .2, .5, and .8 (J. Cohen, 1988, 1992).

Demographic characteristics of the sample were analysed. Those who met the 'diagnostic' criteria for FA according to the YFAS (FA group), were compared to those who did not (Non-FA group) using independent samples *t*-tests and Chi square analyses. Any demographic variables found to differ between groups were controlled for in the subsequent regression analyses. To determine which nutritional food attributes were most associated with perceptions of problematic and ‘addictive’ eating behaviour, correlations between mean problematic food ratings and ratings of addictive potential and the objective nutritional attributes for all foods were conducted. As suggested by Cohen, the values of Pearson’s correlation coefficient (*r*) for small, medium and large effects, respectively, are .1, .3, and .5 (J. Cohen, 1988, 1992). To explore any differences in perceptions of perceived problems and addictive potential in the FA and Non-FA groups, descriptive statistics and independent sample *t*-tests were conducted. Finally, hierarchical multiple regression analyses were undertaken to examine whether the objective food attributes which predicted these perceptions differed between groups. All objective variables were entered using the stepwise method, added to the model in order of the size of their correlation with the predictor variable, starting with the largest, since no *a priori* hypotheses were made regarding the factors which may influence these relationships.

To check for multicollinearity between predictor variables, the variance inflation factor (VIF) and tolerance statistics were examined. Multicollinearity was assumed if the VIF statistic was greater than 10 (Bowerman & O'Connell, 1990), or the tolerance value below .20 (Menard, 1995; O’Brien, 2007). Those variables violating either of these conventions were removed from the model. To examine the difference between the value the model predicts and the value observed in the data, residual statistics were examined. A standardised residual of less than -3 or greater than 3 indicated that an observation was a statistical outlier. Cook’s distance scores were also examined to measure the overall influence of a case on the model, whereby a score of greater than 1 indicated that a case disproportionately influenced the model (Cook & Weisberg, 1982).

5.4 Results

5.4.1 Demographic and YFAS results

Of the final sample (N=929), 10.30% met the YFAS criteria for food addiction (N=96). Across the full sample the mean number of YFAS symptoms endorsed was 2.05 (± 1.65) and the mean YFAS 'sum-score' was 3.19 (± 3.20). In the whole sample, 17% of participants considered themselves to be "addicted" to a food or food ingredient(s) (N=158), corresponding to 42.7% of FA participants (N=41), compared to 14% of Non-FA individuals (N=117). When asked to specify which foods these individuals considered themselves to be "addicted" to, the most commonly identified foods and ingredients were confectionary or sugary foods (N=54), bread/carbohydrates (N=25) and chocolate (N=20).

Independent samples *t*-tests were conducted to compare the differences in the FA and Non-FA groups on a range of demographic variables. As outlined in *Table 11*, participants in the Non-FA group were significantly older than the FA group ($t(132.96) = 2.42$, $p < .05$, $d = .22$), however these groups did not differ in BMI ($t(107.25) = -1.35$, $p = .18$). As to be expected (and by definition), the FA group had a significantly higher YFAS symptom count and sum-score compared to the Non-FA group ($t(927) = 21.69$, $p < .001$, $d = 2.33$ and $t(103.86) = 19.83$, $p < .001$, $d = 3.06$), respectively. As age has been reported to affect food taste and perceptions (Buckland, Dalton, et al., 2015; Kremer, Bult, Mojet, & Kroeze, 2007; Oakes & Slotterback, 2001), age was controlled for in subsequent regression analyses.

Chi-square analyses revealed no differences in frequency distribution between the FA and Non-FA groups on gender ($\chi(1) = 2.41$, $p = .12$), ethnicity ($\chi(15) = 11.71$, $p = .70$), education level ($\chi(8) = 4.76$, $p = .78$), smoker status ($\chi(4) = 2.42$, $p = .66$) or state hunger ($\chi(6) = 5.05$, $p = .54$). However, there was a significant difference in frequency distributions the between FA groups based on current diet status ($\chi(1) = 42.90$, $p < .001$), such that 43.80% of those in the FA group were currently dieting, compared to 16.10% of the Non-FA group. As current diet status is likely to affect food perceptions (Buckland, Dalton, et al., 2015; Knight & Boland, 1989; Oakes & Slotterback, 2002; Véronique

Provencher, Polivy, & Herman, 2009) the percentage of dieters in each group was controlled for in the subsequent regression analyses.

Table 11. Demographic and YFAS statistics of the full sample, the FA group and the Non-FA group

Participant characteristic	Total sample (N=929)		FA (N=96)		Non-FA (N=833)		*t*-test	Bootstrapped 95% CI		Effect size
	M	SD	M	SD	M	SD	*t*	Lower	Upper	*d*
Age	29.63	11.94	27.31	9.59	29.89	12.16	2.42*	.47	4.69	.22
BMI	23.04	4.14	23.72	5.39	22.96	3.96	1.35	-1.89	.36	.18
Mean YFAS 'symptom count'	2.05	1.65	4.86	1.39	1.73	1.34	21.69 ***	-3.42	-2.85	2.33
Mean YFAS 'sum-score'	3.19	3.20	9.61	3.46	2.45	2.18	19.83 ***	-7.88	-6.45	3.06

Note: Independent samples *t*-test conducted between FA and Non-FA groups. Bootstrapped 95% CI and effect size refer to *t*-test. * = p<.05, ** = p<.01, *** = p<.001.

5.4.2 Associations between objective and subjective attributes of foods

In order to investigate which ingredients or food attributes displayed the strongest associations with ratings of perceived problematic eating behaviours or addictive potential, correlation analyses were conducted. Mean ratings for all seventy foods, as rated by the full sample[1], were utilised.

As depicted in *Table 12*, problematic food ratings and perceived addictive potential correlated most strongly with energy density (both p <.001), followed by total fat content per 100g (both p <.001). Both perceived problems and addictive potential correlated positively with total carbohydrate content, sugar

[1] When taking into account attrition, invalid responses, and exclusion of foods due to dietary restrictions, each food received ratings from between 134 (cottage cheese) and 439 (crisps) participants across the full sample.

content and saturated fat content (all p <.001). Perceived problematic food ratings, but not addictive potential correlated significantly with protein per 100g (p <.05).

These results demonstrate that the present sample were more likely to rate foods higher in energy density, total carbohydrate, sugar, total fat and saturated fat content as being associated with problematic eating behaviours and addictive potential. The sample were more likely to rate foods higher in protein content as being associated with problematic eating behaviours.

Table 12. Correlations between subjective ratings of associated problems and addictive potential and objective attributes of all 70 foods, as rated by the full sample (N=929)

	1.	2.	3.	4.	5.	6.	7.	8.
1. Associated Problems	-							
2. Addictive Potential	.94***	-						
3. Energy Density	.60***	.66***	-					
4. Protein per 100g	.15*	.11	.23**	-				
5. Total Carbohydrate per 100g	.36***	.46***	.69***	-.26***	-			
6. Sugars per 100g	.29***	.41***	.37***	-.32***	.55***	-		
7. Total Fat per 100g	.53***	.54***	.78***	.32***	.13	.13	-	
8. Saturated Fat per 100g	.44***	.49***	.58***	.27***	.05	.20**	.79***	-

* p < .05, ** p < .01, *** p < .001

5.4.3 Subjective food perceptions across FA groups

To examine whether the FA and Non-FA groups differed in their perceptions of the associated problems and ‘addictive potential’ of the food stimuli, descriptive statistics were examined and independent *t*-tests were employed to compare mean ratings between these groups [2].

Ratings of associated problems ranged from 1.38 to 5.17 in the FA group (M: 2.89, ± .93). Cookies, pizza, brownies, chocolate and crisps were rated as having the most associated problems whilst green beans, grapefruit, cucumber, carrots and jelly the least in this group. In the Non-FA group, ratings of perceived problems ranged from 1.28 to 4.24 (M: 2.31, ± .71), with pizza, cookies, grated cheese, crisps and chocolate rated as being the most problematic and green beans, grapefruit, cucumber, carrots and broccoli the least. Ratings of associated problems differed significantly between the FA and Non-FA groups (t (128.82) = 4.14, p <.001, 95% CI [.30, .85], d = .79), with the FA group rating foods as more problematic, on average.

For perceived addictive potential of foods, the FA group's ratings ranged from 1.29 to 5.65 (M: 3.31, ± 1.22), whereby cookies, chocolate, doughnuts, crisps and brownies were perceived as having the greatest addictive potential and green beans, yoghurt, cod, cucumber and grapefruit the least. In the Non-FA group, ratings of addictive potential ranged from 1.24 to 5.23 (M: 2.75, ± 1.01), with chocolate, crisps, pizza, brownies and cookies being rated as most likely to have addictive potential and green beans, cucumber, grapefruit, butter beans and broccoli the least. The FA and Non-FA groups differed significantly in their ratings of strength of addictive potential (t (138) = 2.94, p <.01, 95% CI [.17, .92], d = .54), with the FA group rating foods as having a greater addictive potential, in general.

5.4.4 Predictors of subjective perceptions of foods according to YFAS 'diagnosis'

In order to further explore the associations between perceived problems and addictive potential and objective measurements of macronutrient composition in the FA and Non-FA groups, multiple hierarchical regression analyses were

[2] When taking into account attrition, invalid responses, and exclusion of foods due to dietary restrictions, each food received ratings from between 11 (chicken breast) and 54 (carrots) participants in the FA group and between 121 (cottage cheese) and 396 (crisps) participants in the Non-FA group.

conducted. As age and dieting status differed between the FA and Non-FA groups, these variables were controlled for and entered as covariates in step one of each model.

5.4.4.1 Perceived associated problems

The analyses revealed that, in the FA group, at stage one, age and percentage of dieters did not contribute significantly to the model, ($F(2, 67) = .41$, $p = .67$) and accounted for 1.20% of the variation in ratings of perceived problems. In stage two, introducing energy density explained an additional 37.10% of variation in problem ratings and this change in R^2 was significant ($F(3, 66) = 13.66$, $p < .001$). The final model accounted for 38.30% of the variance in ratings of perceived problems. These results are outlined in *Table 13*.

In the Non-FA group, at stage one, age and percentage of dieters did not contribute significantly to the model, ($F(2, 67) = 3.09$, $p = .05$) and accounted for 8.40% of the variation in ratings of perceived problems. In stage two, introducing energy density explained an additional 35.90% of variation in problem ratings and this change in R^2 was significant ($F(3, 66) = 17.53$, $p < .001$). The final model accounted for 44.40% of the variance in ratings of perceived problems. These results are outlined in *Table 13*.

Table 13. Hierarchical regression results of objective attributes predicting perceived associated problems when controlling for age and diet status in the FA and Non-FA groups

	FA				Non-FA		
	B	SE *B*	*β*		*B*	SE *B*	*β*
Step 1				*Step 1*			
Constant	3.67	2.15		Constant	2.08	2.05	
Age	-.04	.07	-.08	Age	-.02	.05	-.07
Diet status	.00	.01	.04	Diet status	.06	.04	.23
Step 2				*Step 2*			
Constant	2.50	1.72		Constant	3.13	1.62	
Age	-.01	.05	-.03	Age	-.05	.04	-.15
Diet status	.00	.01	-.03	Diet status	.00	.03	-.01
Energy density	.36	.06	.62***	Energy density	.28	.04	.63***

* $p < .05$, ** $p < .01$, *** $p < .001$

5.4.4.2 Perceived addictive potential

In the FA group, age and percentage of dieters did not significantly contribute to the model ($F(2, 67) = 2.49$, $p = .09$) and accounted for 6.90% of variance in ratings of addictive potential. When energy density was introduced at stage 2, this model accounted for an additional 40.90% of variance and this change in R^2 was significant ($F(3, 66) = 20.18$, $p < .001$). The final model accounted for 47.80% of variance in addictive potential (*Table 14*).

In the Non-FA group, at stage one, percentage of dieters, but not age could significantly predict perceived addictive potential. This model was significant ($F(2, 67) = 5.65$, $p < .01$) and accounted for 14.40% of variance in ratings of addictive potential. When energy density was introduced, diet status became a non-significant predictor but the model accounted for an additional 36.30% of variance with a significant change in R^2 (F(3, 66) = 22.63, p <.001). The final model accounted 50.70% of variance in addictive potential (*Table 14*).

Table 14. Hierarchical regression results of objective attributes predicting perceived addictive potential when controlling for age and diet status in the FA and Non-FA groups

	FA				Non-FA		
	B	SE *B*	*β*		*B*	SE *B*	*β*
Step 1				*Step 1*			
Constant	5.84	2.74		Constant	1.61	2.83	
Age	-.12	.08	-.20	Age	-.03	.07	-.06
Diet status	.01	.02	.10	Diet status	.11	.05	.34*
Step 2				*Step 2*			
Constant	4.22	2.08		Constant	3.12	2.17	
Age	-.08	.06	-.14	Age	-.06	.06	-.14
Diet status	.00	.01	.02	Diet status	.03	.04	.09
Energy density	.50	.07	.65***	Energy density	.40	.06	.63***

* p < .05, ** p < .01, *** p < .001

5.5 Discussion

One supposition throughout the literature on FA is that certain substances present in some foods are addictive (for example; Davis et al., 2014; Gearhardt, Davis, et al., 2011; Gearhardt, Grilo, et al., 2011). In order to investigate this, a standardised food image-based platform for systematically assessing subjective perceptions of a range of foods, was adopted. This aimed to explore which objectively measured food attributes or ingredients were most strongly associated with individuals' perceptions of problematic eating behaviour or addictive potential, and whether the objective attributes influencing these perceptions differed according to a YFAS-defined FA 'diagnosis'.

The results of the present study identified a small proportion (10.30%) of the sample who met the YFAS criteria for 'food addiction', on a par with previous research in non-clinical samples (Gearhardt et al., 2009b; C. G. Long et al., 2015; Markus et al., 2017; Pursey, Stanwell, Gearhardt, et al., 2014). However, 17% of the sample perceived themselves to be "addicted" to a specific food(s) when explicitly asked. This increased prevalence of 'self-perceived food addiction' (SPFA; Meadows, Nolan, & Higgs, 2017) compared to the 'diagnostic' YFAS criteria for FA was also reported by Meadows et al. (2017) in samples of University students and adults. The authors reported that, in the University students, 40% of the individuals who were self-perceived food addicts endorsed more than three of the YFAS criteria, the minimum number required for a dichotomous 'diagnosis' of FA, but did not endorse the 'clinically significant impairment or distress' criteria necessary for a FA 'diagnosis' according to the YFAS. Such results suggest that there may be a subgroup of individuals who report problematic eating behaviours which they perceive to be representative of an 'addiction', but such behaviours are not sufficient to warrant clinical significance. This suggestion is supported by Hardman et al. (2015), who reported that individuals may mislabel various problematic eating behaviours as an 'addiction', for ease of understanding.

Analysis of the demographic statistics found that those individuals meeting the YFAS criteria for 'food addiction' were significantly younger than the Non-FA group and significantly more likely to be currently dieting. As food perceptions have been found to differ with age (Oakes & Slotterback, 2002), and dieting is said to play a critical role in human eating behaviour (Lowe, 1993) and food perceptions (Buckland, Dalton, et al., 2015), both age and percentage of dieters were controlled for in subsequent regression analyses.

Results of the correlation analyses revealed that energy density was the food attribute most strongly associated with ratings of problematic eating behaviours and addictive potential, such that individuals perceived energy dense foods as more likely to be associated with problematic and ‘addictive’ eating. Total fat and saturated fat content were also a significant positive correlates of problematic and addictive food ratings, and correlated to a greater strength compared to total carbohydrate and sugar content. These results suggest a greater role of fat content in the perception of foods which may induce problematic eating behaviours or contain addictive potential.

Protein content was positively associated with ratings of associated problems, but not addictive potential, in that foods higher in protein were more likely to be rated as problematic. It is likely that protein consumption in isolation may not be associated with problematic eating behaviours, but only when protein and fat are presented in combination, such as in dairy products. High fat foods, possibly in the absence of protein, such as fried food or confectionery, may still be regarded as ‘problematic’ or possessing ‘addictive potential’.

In order to further explore these associations as a function of YFAS-defined FA ‘diagnosis’, descriptive statistics were employed. Both the FA and Non-FA groups were generally consistent in their identification of which foods they considered to be most problematic and addictive. High fat sweet foods, such as cookies, chocolate and brownies, and high fat savoury foods, such as pizza, crisps and cheese, were generally rated as being most associated with problematic eating behaviours and addictive potential in both groups. However, the FA group reported significantly higher overall ratings of associated problems and addictive potential compared to the Non-FA group. These results suggest that individuals meeting the YFAS criteria for FA subjectively perceive certain foods to be more likely to prompt problematic eating behaviours or possess an ‘addictive’ element, compared to those not meeting the YFAS criteria for FA. These results are supported by a recent study by Markus et al. (2017) who reported that individuals who met the YFAS criteria for FA were more likely to report having problems with high fat sweet and high fat savoury foods.

In order to explore whether the objective food attributes influencing the perceptions of associated problems or addictive potential differed according to FA group, multiple hierarchical regression analyses were conducted. The results revealed that, in both the FA and Non-FA groups, energy density alone was the most significant positive predictor of ratings of both associated problems and addictive potential, whereby energy dense foods were more likely to be rated as having greater associated problems and addictive potential. These results reveal a consistency between FA and Non-FA groups in attributes which predict problematic or 'addictive' food ratings. This finding contrasts strongly with research suggesting that the associations between energy dense or highly palatable foods and perceptions of problematic or addictive-like eating is unique to, or enhanced in, YFAS-defined 'food addicts' (Schulte et al., 2015).

A prominent feature of the present study was that energy density was revealed to be an important predictor of ratings of both associated problems and addictive potential, irrespective of YFAS group, and played a greater role in these perceptions than fat or carbohydrate content individually. When applied to actual food intake, these results are supported by Bell, Castellanos, Pelkman, Thorwart, and Rolls (1998) who reported that when fat and carbohydrate content are kept consistent across meals varying in energy density, participants are found to overconsume in high energy density conditions, suggesting an effect of energy density on energy intake, independent of fat or carbohydrate composition. In individuals susceptible to overconsumption, this increase in energy intake may be perceived as problematic or inducing 'addictive' eating behaviours. This is further supported by research demonstrating the role of energy density in increasing energy intake (Ledikwe et al., 2006a; Prentice & Jebb, 2003; Stubbs, Ritz, Coward, & Prentice, 1995), possibly due to the high reward value (Rogers & Brunstrom, 2016) and lower satiating value per calorie of energy-dense foods (Blundell et al., 2014). Conversely, low energy density foods provide more nutrients per calorie and are associated with better diet quality (Andrieu, Darmon, & Drewnowski, 2006; Ledikwe et al., 2006b; Monsivais & Drewnowski, 2007), successful weight management (Buckland, Dalton, et al., 2015) and long-term weight loss (Shick et al., 1998). In light of this, reducing the consumption of energy dense foods may be a worthwhile strategy for individuals prone to overconsumption (Bell et al., 1998; Ledikwe et al., 2006a).

Of particular interest are the low associations between ratings of problematic foods and addictive potential with sugar content. There is an ever-escalating opinion that sugar and/or sweetness is central to the expression of ‘addictive’ eating behaviours (Ahmed, 2012; Avena et al., 2008; Colantuoni et al., 2002; Rada et al., 2005). However, the present results demonstrated low (though nevertheless statistically significant) correlations between ratings of problematic eating behaviours or addictive potential, and no independent ability of sugar content in predicting these ratings when controlling for ED, even in the FA group. Such findings reinforce the conclusions of Benton (2010) that the plausibility of sugar addiction is not strongly supported in human studies. In addition, it is necessary to distinguish between the effects of sweetness in general and sugar related sweetness in particular.

In addition to these results, the present study examined the validity of a novel platform for assessing individuals’ perceptions of a wide range of foods across different consumers. The platform has already been used to successfully characterise foods based on their satiety value (Buckland, Stubbs, et al., 2015), and to examine dieters’ and non-dieters’ perceptions of the foods most associated with successful weight management (Buckland, Dalton, et al., 2015). Although this tool will benefit from further validation using empirical data from perceptions of real-life foods or a food choice paradigm, the present study provides promising support for the use of this platform in early identification of those foods considered most implicated in individuals’ perceptions of problematic or ‘addictive’ eating behaviours, especially in those vulnerable to overconsumption. Therefore, this study represents a preliminary step towards providing an objective reference point for which foods might prompt overconsumption.

5.5.1 Limitations

Similarly to Chapter 3 and Chapter 4, the results of this study are limited by self-report data which is prone to misreporting (Macdiarmid & Blundell, 1998). Furthermore, the final sample included a disproportionately large amount of females and targeting a University population as a source of recruitment limits generalisability of the results to a broader population. However, a large number of responses were obtained by utilising an online survey. Despite this large sample size, separating the FA and Non-FA groups and only presenting diet-congruent images (i.e., not any which the individual had an allergy or avoidance towards) resulted in an inconsistent number of individuals rating each food (for example, one food only received 11 ratings from individuals in the FA group), a limitation of the study design. There are also inherent limitations of the Food Perceptions Platform which should be addressed in future research. Firstly, portion sizes were subjectively determined by the researchers to comply with their norms, thus this methodology would benefit from standardisation of portion sizes across food. In addition, the Platform involves individuals' responses to food images, rather than actual foods. Therefore, the relevance of these findings to actual food intake given the absence of feeding cues and sensations must be interpreted cautiously.

5.5.2 Conclusions

In conclusion, the results of the present chapter employed objective nutritional data, rather than the opinion of the authors to reveal consistent associations between energy dense foods and individuals' perceptions of what constitutes a 'problematic' food or a food with 'addictive potential'. Although YFAS-defined 'food addicts' largely reported higher ratings of perceived problems and addictive potential in response to the study food stimuli, no food attributes or ingredients were revealed to be specific to YFAS-defined 'food addicts' in influencing these perceptions. These results do not rely on arbitrary assignment of foods as being processed or "hyperpalatable", but are based on the actual perceptions of subjects and the actual objective attributes of the foods themselves.

However, such findings should not be taken out of context to suggest that foods high in energy density possess any capacity to prompt behaviours or biological alterations to the same extent as the neurological adaptations seen when psychoactive drugs are consumed in excess. Foods are made more palatable in the modern food environment through elevating fat, carbohydrate or energy density contents (Davis, 2013b; Gearhardt, Davis, et al., 2011; Schulte et al., 2015), but this does not automatically make such foods addictive (Klurfeld, Foreyt, Angelopoulos, & Rippe, 2013; Markus et al., 2017). Whilst it is important to understand why individuals are drawn to consume and overconsume these foods in order to develop treatment and prevention approaches for appetite-related difficulties, researchers should be cautioned against the use of the term ‘addiction’ in describing certain (over)eating behaviours (Blundell et al., 2014; Ziauddeen et al., 2012b). This term implies that a certain substance or ingredient is implicated in promoting such behaviours and its continued use risks elimination of the personal responsibility of overconsumption (i.e., “I ate too much [insert food] because it’s addictive”).

Summary

- The energy density of food was revealed to be the attribute most strongly associated with individuals’ ratings of increased problematic eating behaviours and addictive potential.
- No objective nutritional attributes of foods could discriminate between FA and Non-FA participants in predicting the perceived problematic associations and addictive potential of foods.

Chapter 6

An investigation of energy compensation as a function of YFAS score: no evidence of blunted homeostatic appetite control in YFAS-defined 'food addicts'

Aims

- Primary: To determine whether high-YFAS scoring individuals exhibit an impairment to their homeostatic appetite control by displaying blunted satiety in response to a laboratory-controlled preload paradigm.
- Secondary: To explore the association between physical activity level and YFAS scores.

6.1 Abstract

Background: It is frequently assumed in the literature that food addiction (FA), like drug addiction, reflects a hedonic drive to overconsume, therefore homeostatic control of energy intake and expenditure should not differ across YFAS scores. A laboratory study objectively measuring habitual physical activity levels and homeostatic appetitive responses to a covertly manipulated preload paradigm in individuals varying in YFAS score was therefore conducted. It was hypothesised that individuals will display similar physical activity patterns and energy compensation in response to preloads differing in energy content, irrespective of scores on the YFAS.

Method: A laboratory-based study of 24-hour energy intake (EI) and habitual 7-day energy expenditure (EE) and physical activity (PA) using a single-blind, counterbalanced, repeated measures design was conducted. 34 female participants (age: 26.24 ± 7.47, BMI: 22.37 ± 4.35) were grouped according to their score on the YFAS as either low (LFA; YFAS score = 0; N=10), moderate (MFA; YFAS score = 1-2; N=12), or high FA (HFA; YFAS score = ≥3; N=12) and matched for BMI and age across groups. Participants completed a preliminary anthropometric assessment (RMR, body composition, VO_{2Max}, eating behaviour questionnaires, 1-week habitual PA) followed by 3 meal days. Meal days included a fixed-energy breakfast (25% RMR) followed (+3-h) by a high energy (HEP), low energy (LEP), or no energy (control; NEP) preload. Lunch (+1h), dinner (+3h) and evening snacks were presented a*d libitum* to measure 24-h EI. Subjective ratings of appetite sensations were obtained throughout the day.

Results: The HFA group had a significantly lower VO_{2Max} compared to MFA and LFA, accompanied by a significantly lower habitual PA level and fewer minutes of moderate-to-vigorous PA in HFA compared to LFA. The HFA group also had significantly higher binge eating and disinhibition and less positive mood compared to MFA and LFA. There were no differences across groups in ratings of appetite sensations, with the HEP condition suppressing hunger, desire to eat and prospective consumption and encouraging fullness to a greater extent compared to LEP and NEP across the day in all groups.

Conclusions: This study is the first to explore FA within an objectively measured energy balance framework. The results demonstrated that an increasing YFAS score was associated with lower PA and lower cardiovascular fitness, but no relationship between increasing YFAS score and a dysfunction

of homeostatic appetite control was revealed. All subjects overconsumed throughout the day following a high energy preload, highlighting the importance of a low energy density diet in regulating energy balance. The YFAS appears to detect individuals with a tendency towards binge eating, disinhibition and a less positive mood, yet such traits do not seem to be reflected in their eating behaviour under laboratory conditions. Therefore, the YFAS does not seem to be a useful tool in characterising individuals with poor satiety responsiveness or a susceptibility towards a positive energy balance arising from a loss of homeostatic control over appetite.

6.2 Introduction

To date, the literature on food addiction (FA) has focused primarily on the behavioural and neurological similarities between ingesting palatable foods and psychoactive drugs (see Chapter 1). Considerable evidence in rodents and humans suggests that the drive to consume drugs of abuse results from dysfunctions in the hedonic system of reward (Ahmed & Koob, 1998; Koob & Le Moal, 1997; T. E. Robinson & Berridge, 1993). As hedonic dysregulation has also been demonstrated following presentation and consumption of highly palatable foods (Berthoud, 2004; Kelley & Berridge, 2002; Lutter & Nestler, 2009; Volkow & Wise, 2005), this has led to suggestions that dysfunctions in the hedonic system of reward responsiveness may be responsible for overconsumption of food to the extent which it may resemble an 'addiction' (Davis & Loxton, 2014; P. M. Johnson & Kenny, 2010; Parylak, Koob, & Zorrilla, 2011). This idea is discussed further in Chapter 5, which revealed that highly energy dense foods were more likely to be perceived as having greater 'addictive potential' or associated with 'problematic' eating behaviours. However, according to the YFAS, individuals who met the criteria for 'food addiction' individuals did differ to those who did not in their perceptions of problematic or 'addictive' foods. In contrast, however, little attention has been given to the role of the homeostatic system of appetite control in relation to FA.

The homeostatic system of appetite control refers to the regulation of a complex network of hormonal and neuropeptide signalling (Schwartz, Woods, Porte, Seeley, & Baskin, 2000), influencing the initiation and termination of eating and promoting stability of energy stores in the body over time. Meal initiation is driven by hunger peptides, including neuropeptide Y and ghrelin, released prior to meal initiation, whilst meal termination is encouraged by satiety signals, released in response to food ingestion. These include cholecystokinin (CCK) and glucagon-like peptide 1 (GLP-1), released from the digestive tract, and leptin, originating from adipose tissue (Blundell, 2006; Blundell, Halford, King, & Finlayson, 2016). Such signals differentially act to encourage satiation, the termination of the current eating episode, and satiety, the post-meal suppression of hunger and inhibition of further eating (Blundell & Rogers, 1991).

Satiety can be objectively measured in the laboratory through the preload paradigm. This involves the presentation of a fixed quantity of a food, followed by access to an *ad libitum* meal (Green, Delargy, Joanes, & Blundell, 1997; Kissileff, 1985). Studies have demonstrated that subjects tend to partially compensate for the energy contained within the preload by reducing subsequent intake (Flood & Rolls, 2007). However, this compensation often does not outweigh the increase in energy intake (EI) from the preload (Kral & Rolls, 2004; Walike, Jordan, & Stellar, 1969), resulting in overconsumption and demonstrating imperfect homeostatic control over satiety. The accuracy of compensation is susceptible to numerous individual differences. Whilst improvements in satiety and EC have been demonstrated in lean (Shide, Caballero, Reidelberger, & Rolls, 1995) and physically active (S. J. Long, Hart, & Morgan, 2002; Martins, Kulseng, Rehfeld, King, & Blundell, 2013; Sim, Wallman, Fairchild, & Guelfi, 2014) individuals, increasing age (S. L. Johnson, 2000), body mass (Lieverse, Masclee, Jansen, Lam, & Lamers, 1998; Spiegel, Shrager, & Stellar, 1989), dietary restraint (Lluch, King, & Blundell, 2000; Rolls et al., 1994; Spencer & Fremouw, 1979) and the presence of binge eating (Finlayson, Arlotti, Dalton, King, & Blundell, 2011) have all been revealed to have a detrimental effect on appetite control. Given this bias of the homeostatic appetite regulation system towards maintaining a positive energy balance (Schwartz et al., 2003) and the ability of humans to eat well beyond individual metabolic needs (Levin, 2006), individual variability in the mechanisms which may modulate satiety responsiveness are an important area of research.

Homeostatic appetite control does not occur in isolation, but rather is part of a complex network of processes regulating energy balance (Blundell & King, 2000). Specifically, the contribution of physical activity (PA) on appetite control is an important area of investigation (Blundell, Gibbons, Caudwell, Finlayson, & Hopkins, 2015), especially given the bias towards sedentariness (physical inactivity) in today’s society (Edholm, Fletcher, Widdowson, & McCance, 1955). The beneficial effects of behavioural energy expenditure on appetite control have long been demonstrated (Almiron-Roig et al., 2013; Blundell, 2011; King et al., 2009; S. J. Long et al., 2002; Martins, Morgan, Bloom, & Robertson, 2007; Mayer, Roy, & Mitra, 1956), whilst, on the other hand, sedentariness is often found to be associated with increasing adiposity and weakened satiety mechanisms (Stubbs, Hughes, Johnstone, Horgan, et al., 2004; Stubbs, Hughes, Johnstone, Whybrow, et al., 2004). However, due to a lack of empirical studies, the contribution of so-called FA on energy balance is currently unclear.

To date, the literature surrounding food addiction assumes that the criteria included on the 25-item Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009b) are sufficient to define the behaviours of “food addicts”. However, no studies have investigated the potential role of FA in energy balance, and only three studies have investigated food addiction in relation to actual food intake (C. G. Long et al., 2015). Of these, Pedram et al. (2013), reported retrospective self-report intake and found a significantly greater calorie intake from fat and protein in the FA group, compared to a non-FA group. However, the retrospective nature of this study meant limitations relating to self-reporting were likely to have been present (Macdiarmid & Blundell, 1998). Gearhardt, Yokum, et al. (2011) measured the functional magnetic resonance imaging (fMRI) activation in response to oral delivery and anticipated delivery of a chocolate milkshake or unflavoured control beverage. The authors reported significant correlations between brain activation and anticipated and actual intake of the milkshake, and greater activation in the FA vs non-FA groups. The enhanced brain activation was demonstrated in areas known to be implicated in reward-processing, such as the caudate and medial orbitofrontal cortex (Berridge & Kringelbach, 2008; Kawagoe, Takikawa, & Hikosaka, 2004), and food intake was not objectively measured, therefore, this study cannot be used to draw conclusions regarding the homeostatic appetite control of “food addicted” individuals. Thirdly, Davis et al. (2014) measured cravings and snack food consumption of 23 ‘food addicted’ and ‘non-food addicted’ individuals in response to an appetite-suppressive stimulant drug, methylphenidate, or a placebo. The authors reported that, unlike the Non-FA group, the FA group demonstrated no reduction in snack food intake in the methylphenidate condition compared with the placebo condition, suggesting differences in eating behaviour between those meeting the YFAS criteria for FA and those who do not. However, methylphenidate acts to block dopamine (DA) transporters and lower extracellular DA concentrations (Volkow et al., 2001), suggesting that the action of methylphenidate in reducing appetite is mediated by hedonic systems (Martin, Sloan, Sapira, & Jasinski, 1971). Given the focus of the literature related to FA on hedonic drivers to overconsume, it is frequently assumed that FA is a hedonic phenomenon, suggesting that homeostatic control of eating and EE should not be affected by YFAS score. However, as FA is yet to be tested within an energy balance framework, the contribution of YFAS scores in the homeostatic regulation of energy balance is currently unknown.

One example of this is the lack of understanding of the contribution of physical activity levels on the expression of so-called FA. Given that FA is assumed to be hedonically driven, as previously discussed, PA should play no role in the expression of FA symptomatology, though this is yet to be empirically tested. Furthermore there is inconsistency in reporting the associations between the YFAS and body mass index (BMI; see Chapter 2 for a review), though this is possibly due to under-reporting of self-reported BMI (Visscher, Viet, Kroesbergen, & Seidell, 2006). However, many studies have concluded that YFAS-defined ‘food addicts’ display an increased BMI, suggesting that the presence of ‘food addiction’ may be responsible, in part, for overconsumption and a susceptibility towards a positive energy balance. In order to elucidate the specific role of FA symptomatology on energy balance, it is necessary to objectively measure EE through PA and control for any confounding effects which BMI may have on this relationship.

In light of this, a laboratory study of food intake and appetite control is required to investigate FA within an energy balance framework, exploring habitual physical activity and the homeostatic control of appetite in so-called ‘food addicted’ individuals. In order to control for their potentially confounding effects, BMI and age were controlled for in the present study and matched across YFAS groups. An objective measure of habitual PA was also included to better understand the effect of PA on energy expenditure as a function of YFAS score.

6.2.1 Objectives

By conducting an objectively measured, laboratory-controlled preload study, an exploratory analysis of FA can be conducted. Specifically, homeostatic control over intake and PA level in individuals across three tertiles of YFAS score will be measured. Covert manipulation of the energy content of two moderately palatable, semi-solid (porridge) preload snacks plus a control condition (water), will precede an *ad libitum* lunch, dinner and evening snacks, allowing 24-hour EI and EC to be measured. A preliminary assessment will also allow for differences in physiological and anthropometric characteristics, as well as objectively-measured habitual physical activity levels, to be compared across individuals varying in YFAS scores.

If food addiction, like drug addiction, is best described as a hedonic dysfunction, it can be assumed that homeostatic control over eating and physical activity level should play no role in the exhibition of so-called food addiction symptomatology. Specifically, for a given BMI, individuals should display similar functional homeostatic responses to food and eating and similar PA levels, regardless of their score on the YFAS, responding to the energy content of a preload by decreasing subsequent energy intake.

Therefore this study hypothesises that: (H_1) Satiety, as measured through subjective ratings of appetite and objectively measured 24-h EI, will not differ between individuals varying in scores on the YFAS. Specifically, (H_1a) participants will reduce energy consumption at lunch, dinner and evening snacks to a greater extent following a high-energy preload, compared to low-energy and no-energy preloads, irrespective of YFAS group. Additionally, (H_2), individuals varying in YFAS scores will not differ in their objectively-measured habitual physical activity levels.

6.3 Methods

6.3.1 Participants

34 female adult (age: 26.24 ± 7.47, BMI: 22.37 ± 4.35) participants were recruited from the staff and student population from the University of Leeds and the surrounding area. Participants were primarily recruited via email distribution lists, including individuals who have participated in previous studies in the Human Appetite Research Unit at the University of Leeds and consented to be contacted for future research. The study was also advertised through the University of Leeds research participant databases, poster advertisements displayed across the University campus and other sites nearby and social media websites.

Eligibility was determined through an online screening questionnaire. Inclusion criteria for the study comprised: aged between 18-55 years, BMI above 18.5kg/m^2, able to attend the Research Unit on four occasions. Participants were excluded if they were: currently dieting to lose or maintain their weight, pregnant or breastfeeding, taking medication known to affect appetite, not regular breakfast consumers, current smokers or ceased within the last 6 months, reported a history of eating disorders, had known allergies or intolerances to or disliked the study foods. Eligible participants were invited to a screening session to confirm their inclusion and were remunerated a total of £30 for their time upon completion of all study days. There were 373 responses to the online screening questionnaire, of which 279 were complete responses. Of these, 38 were invited to participate and started the study protocol. 4 subjects did not complete the full protocol due to work commitments (N=2), aversion of the study foods (N=1) and non-compliance with the study protocol (N=1). Participants provided written informed consent, were fully debriefed upon completion of the full study protocol and all research procedures were reviewed and approved by the School of Psychology Ethical Review Committee.

Participants were recruited according to their score on the YFAS. A tertile split of the continuous YFAS score in a large sample of UK adults (N=667; Chapter 4), revealed that the lowest tertile of the sample gained a score of zero on the

YFAS, the middle tertile scored 1-2, and the upper tertile scored 3 or above (up to a maximum of seven). Therefore, in the present study, participants were grouped into 3 groups according to their YFAS 'symptom count': the 'low FA' (LFA) group included those participants who scored zero on the YFAS (N=10), the 'moderate FA' (MFA) group comprised those who scored 1 or 2 (N=12) and in the 'high FA' (HFA) group were those who scored three or above (N=12). Participants were selected to match for BMI and age across the three groups.

6.3.2 Study design

The study took place between January and December 2016 and followed a single-blind, counterbalanced, repeated measures design, determined by Latin square. Each participant attended the research unit on four occasions: one preliminary assessment visit and three experimental "probe" visits. Each probe visit was separated by a washout period of at least 7 days but no more than 14 days.

For all visits, participants were required to arrive in a fasted state, having not eaten or drunk anything (except water) from 9pm the previous night. Participants were required to abstain from drinking alcohol or engaging in physical activity for 24-hours prior to and during each visit and from drinking caffeinated beverages for 12-hours prior to each visit. Prior to the first probe day, subjects were required to consume their habitual diet and report their food intake in a food diary provided to them during the preliminary assessment (results not recorded). They were instructed to copy this intake on the day before the following two probe days in an attempt to control for baseline hunger levels. Compliance with these instructions was assessed at the beginning of each test session by self-report.

On the probe days, participants arrived at the research unit between 07:00 – 09:00. For all meals, participants were placed in individual feeding cubicles free from distractions and mobile phone use was prohibited during test sessions. Participants were free to leave the research unit in between meals but were instructed not to consume anything except for the food and drinks provided by the researchers during this time.

Ratings of subjective appetitive, gastrointestinal and mood sensations were taken at regular intervals throughout the probe days; every hour throughout the day with the first rating immediately before breakfast, and additional ratings immediately after each meal. State hedonic food preference was assessed using the Leeds Food Preference Questionnaire (LFPQ; Finlayson, King, & Blundell, 2007b; Finlayson, King, & Blundell, 2008) immediately pre- and post- the preload meal.

The design of the test meals aimed to moderate palatability and avoid highly palatable foods. In this way, differences (or non-differences) in EI were assumed to be due to homeostatic factors and not due to drivers associated with hedonic aspects of eating.

6.3.3 Measures

All measures were carried out in the Human Appetite Research Unit at the University of Leeds, with the exception of the online screening questionnaire. All measures followed appropriate standard operating procedures.

6.3.3.1 Eligibility testing

Participants expressing an interest in the study procedure were sent a direct link to an online screening questionnaire (distributed using Qualtrics; Provo, Utah, USA, www.qualtrics.com) to determine eligibility. This included a short demographic questionnaire (measuring general health, lifestyle and wellbeing), information on the study procedure, measurement of ‘food addiction’ (Yale Food Addiction Scale) the short version of the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003).

6.3.3.1.1 Yale Food Addiction Scale

In order to measure self-reported ‘food addiction’, the Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009b) was utilised. This scale is described in detail in Chapter 1.

6.3.3.1.2 International Physical Activity Questionnaire (IPAQ; Craig et al., 2003)

The short-form of the validated International Physical Activity Questionnaire was included in the eligibility survey to screen for physical activity levels. As the IPAQ is prone to over-reporting (Lee, Macfarlane, Lam, & Stewart, 2011), objective assessments of habitual physical activity were also included in the study design.

6.3.3.2 Preliminary assessment

Eligible participants were invited to attend the research unit for a screening day, at least at least 8-days before the first meal day, to measure eating behaviour traits, resting metabolic rate, body composition, and cardio respiratory fitness, and to be fitted with physical activity monitors.

6.3.3.2.1 Eating behaviour traits

The measures of eating behaviour included the Binge Eating Scale (BES; Gormally et al., 1982), Control of Eating Questionnaire (CoEQ; Dalton et al., 2015) and Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985), all of which are described in detail in Chapter 4.

6.3.3.2.2 Resting metabolic rate

Participants' resting metabolic rate (RMR) was measured using whole-body indirect calorimetry fitted with a ventilated hood (GEM Nutrition Ltd.). A clear plastic hemispherical canopy was placed over the participant's head and participants were requested to lie perfectly still but remain awake in a supine position throughout the 45-minute measurement period. Air flow through the hood is completely variable between 20 and 80 litres/min to give optimum conditions for patient comfort. The equation used is the 'modified' Weir Equation: EE = 3.9 *VO2 + 1.1*VCO2. This modified equation does not use a protein factor (Weir, 1949). The average of the last 30 minutes of collection was used to determine RMR. Oxygen uptake and maximal CO_2 are calculated from O_2 and CO_2 concentrations in inspired and expired air diluted in a constant airflow of ~40 L/min (individually calibrated for each participant) and averaged over 30 second intervals. Substrate oxidation (RER) was calculated using standard stoichiometric equations (Peronnet & Massicotte, 1991).

6.3.3.2.3 Body composition

Whole body air-displacement plethysmography using the BodPod (Life Measurement Instruments, Concord, CA, USA) was used to determine subjects' fat mass (FM), fat free mass (FFM) and percentage body fat (%BF). Participants were asked to wear tight-fitting, non-wired clothing and a swim cap. Standing height (cm) was measured using a stadiometer (Seca Ltd.) with shoes removed. Body weight (kg) was measured using electronic calibrated scales. Waist circumference (cm) was measured at participants' navels. Subjects' measured height and weight was used to determine body mass index (BMI; kg/m^2).

6.3.3.2.4 Cardiorespiratory fitness

Cardiorespiratory fitness (VO_{2Max}) was determined using a maximal incremental treadmill test based on the modified Balke protocol (American College of Sports Medicine, 2013). Inactive individuals walked at 5 km/h, active women ran at 8 km/h and active men at 9 km/h, with the incline increasing 2% in the first minute and 1% for each additional minute, until volitional exhaustion. Expired gases (Sensormedics Vmax29, Yorba Linda, USA) and heart rate (HR; Polar RS400, Polar, Kempele, Finland) were measured continuously during the test. Ratings of perceived exertion were collected at the end of each minute using the Borg scale, with score ranging from 6 to 20. The highest 30-second average was considered as the VO_{2Max}. Attainment of true VO_2max was characterised by a plateau in VO_2 with an increase in workload, a respiratory quotient (RQ) of >1 and a HR within 20 beats of age predicted maximum HR (220-age).

6.3.3.2.5 Accelerometry

Accelerometers were used to determine energy expenditure and physical activity during all meal days in addition to habitual energy expenditure and physical activity over 7 routine days (including at least one weekend day). Participants were fitted with a SenseWear armband (SenseWear Armband (SWA); BodyMedia Inc.; Pittsburgh, USA) and activPAL (PAL Technologies Ltd., Glasgow, UK) at the end of the preliminary assessment visit. Participants were instructed to wear the SWA on their non-dominant arm for at least 23 hours per day (awake and asleep, except when showering, bathing or swimming as the device is not waterproof) for the following 7 days. The

SenseWear armband measures motion (triaxial accelerometer), galvanic skin response, skin temperature and heat flux. Proprietary algorithms available in the accompanying software were used to calculate energy expenditure and activity classification. The activPAL was fixed to the non-dominant thigh and participants were instructed to keep it on for the entirety of the following 7 days. The activPAL has a tri-axial accelerometer and an inclinometer, which measures acceleration and inclination of the thigh. ActivPAL software applies proprietary algorithms to calculate information on physical activity (steps and energy expenditure) and body posture (sitting/lying or standing).

6.3.3.3 Probe days

At least 8-days following the preliminary assessment, participants returned to the research unit for their probe days. Upon arrival, a new pair of accelerometers were fitted, and participants were instructed to wear them for 24-hours until the morning following the meal day and return them with the overnight snack box.

6.3.3.3.1 Visual Analogue Scales

At fourteen systematic time points throughout each testing session (immediately before and immediately after consuming each meal, and every 60 minutes until the end of the experimental day), subjects were required to complete Visual Analogue Scales (VAS) using the hand-held Electronic Appetite Rating System (EARS-II; Gibbons, Caudwell, Finlayson, King, & Blundell, 2011). These measured subjective ratings of appetite, mood and gastrointestinal sensations using a 100-mm scale with anchor points at each end, reflecting participants' current state. Each measure and its response scale is described in *Table 15*. This automated monitoring allows the measurement of subjective appetite in free-living conditions (Stratton et al., 1998) and has been shown to be have been successfully used and validated in previous appetite literature (for example; Delargy, Lawton, Smith, King, & Blundell, 1996; Stubbs et al., 2001). The time points at which the ratings were obtained is depicted in Appendix F.

Table 15. Subjective appetitive, gastrointestinal and mood sensations measures and their respective response scales

Measure	Question	Response Scale
Hunger	How hungry do you feel right now?	0 = Not at all hungry 100 = Extremely hungry
Fullness	How full do you feel right now?	0 = Not at all full 100 = Extremely full
Thirst	How thirsty do you feel right now?	0 = Not at all thirsty 100 = Extremely thirsty
Desire to eat	How strong is your desire to eat right now?	0 = Not at all strong 100 = Extremely strong
Prospective consumption	How much food could you eat right now?	0 = A very small amount 100 = A very large amount
Nausea	How nauseous do you feel right now?	0 = Not at all nauseous 100 = Extremely nauseous
Irritability	How irritable do you feel right now?	0 = Not at all irritable 100 = Extremely irritable
Contentedness	How content do you feel now?	0 = Not at all content 100 = Extremely content
Tiredness	How tired do you feel now?	0 = Not at all tired 100 = Extremely tired
Alertness	How alert do you feel now?	0 = Not at all alert 100 = Extremely alert
Bloating	How bloated do you feel?	0 = Not at all bloated 100 = Extremely bloated
Appetite for a meal	How strong is your appetite for a meal?	0 = Not at all strong 100 = Extremely strong
Appetite for a snack	How strong is your appetite for a snack?	0 = Not at all strong 100 = Extremely strong

6.3.3.3.2 Food hedonics

The Leeds Food Preference Questionnaire (LFPQ; Finlayson et al., 2007b; Finlayson et al., 2008) is used to measure explicit liking and implicit wanting towards an array of pictorial food stimuli. The LFPQ was administered to participants immediately before the preload was served, and again immediately after their preload consumption had ceased, in order to measure state food preference in anticipation of and in response to a feeding episode, as a function of the preload condition. The results from the LFPQ were not analysed in the present chapter.

6.3.3.4 Probe day meals

All meals were prepared by the researchers in the research unit following the appropriate standard operating procedures. All foods were weighed before and after consumption to the nearest 0.10g to calculate energy intake (EI) and ensure compliance. All meals were served to participants in individual testing cubicles and provided with appropriate and standardised utensils.

6.3.3.4.1 Fixed energy breakfast

On all three probe days participants were served a standardised, fixed energy breakfast, consisting of yoghurt and muesli, calibrated to provide 25% of individual energy requirements, as determined by RMR. Subjects were instructed they had 15 minutes to consume the meal in its entirety. Any participants not willing or able to do so were rescheduled or withdrawn from the study.

Subjects were offered one cup (300ml) of either tea, coffee (with or without milk) or water. If they chose to include milk in their tea or coffee (40ml) this was excluded from their breakfast. The beverage they chose on their first probe day was repeated on each subsequent probe day. No sugar was offered with their choice of beverage. Details of the breakfast foods and their nutritional compositions are included in *Table 16*. An image of an example breakfast is displayed in *Figure 9*.

After the breakfast session, participants were given a bottle (500ml) of still water and instructed to drink as much water as they liked throughout the day but only from this bottle, tallying the number of times they refilled it. Subjects were instructed to return the bottle with any remaining water with their snack box the following day.

Table 16. Food items and nutritional composition of the fixed-energy breakfast

Food Item	Kcal/100g	Fat/100g	CHO/100g	Protein/100g
Neal's Yard Muesli Base	360	5	70	13
Neal's Yard Raisins	268.60	0	69.30	2.10
Neal's Yard Sultanas	274.70	.40	69.40	2.70
Yeo Valley Natural Yoghurt	82	4.20	6.50	4.60
Sainsbury's Runny Honey	319.50	.20	84.30	.40
Sainsbury's Semi-Skimmed Milk	50.00	1.10	4.80	3.60
Water	0	0	0	0

Figure 9. Image of the fixed-energy breakfast served to participants (displayed with coffee)

6.3.3.4.2 Mid-morning preload

180-minutes after breakfast was served, the preload snack was served to participants. The order in which participants received each of the three preload conditions was determined using counterbalancing and participants were blinded to the condition until they received it. The three preloads included two experimental semi-solid porridge conditions and one no-energy control condition (water) and were all served with an accompanying glass (150ml) of water. Porridge was chosen for its familiarity, ease of manipulation and its semi-solid form is advantageous over liquid preloads in encouraging energy compensation (Almiron-Roig et al., 2013). Additional ingredients were added to manipulate the energy density of each experimental preload, to form a high energy density (HEP) and low energy density (LEP) preload. Both porridge conditions were matched for weight and volume as, in the absence of accustomed feeding cues, the weight and volume of a preload can alter satiety (Bell & Rolls, 2001; Blundell et al., 2010). Percentage fat, carbohydrate (CHO) and protein content were also matched across experimental conditions. Both experimental preloads were matched for taste, pleasantness and sweetness in a pilot study (N=6) in order to control for the sensory and hedonic drivers of EI. The no-energy control preload (NEP) consisted of water of the same volume as the experimental preloads. By including this control NEP condition, EI following both the HEP and LEP conditions can be compared to baseline EI.

Participants were instructed that they had 15 minutes to consume the preload and accompanying water in their entirety. The macronutrient and energy density composition of the preloads in all conditions, according to manufacturer labelling, is outlined in *Table 17*. Images of each of the preload conditions are displayed in *Figure 10*.

Table 17. Food items and nutritional composition of the three preloads

Preload	Volume (g)	Kcal	% CHO	% Fat	% Protein	Energy Density
HEP	295.50	700.50	39.50	46.80	13.70	2.37
LEP	295.50	257.50	39.10	46.40	14.50	.87
NEP	295.50	0	0	0	0	0

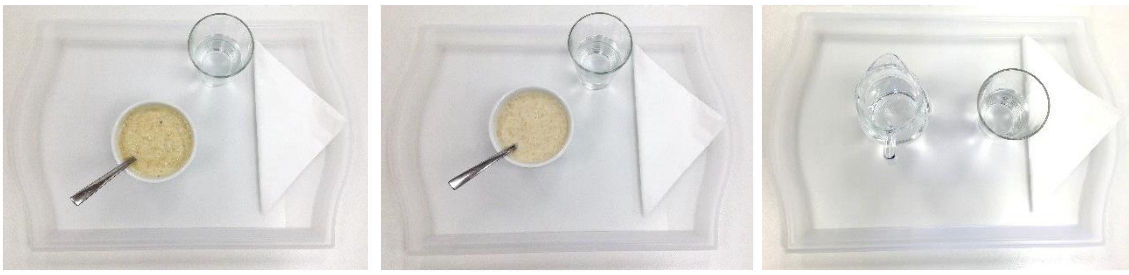

Figure 10. Images of the preload meals served to participants (from left: HEP, LEP, NEP)

6.3.3.4.3 *Ad libitum* lunch

60-minutes after the preload was served, an *ad libitum* lunch meal was served to participants. 60-minutes was chosen as the delay between preload and lunch as it has been reported to take at least 20-minutes for the first post-absorptive effects of the preload to affect energy levels (Reid & Hetherington, 1997), yet a delay of two hours led to an insufficient level of gastric filling to affect satiety (Porrini et al., 1997). The lunch consisted of tomato and herb risotto and a salad of chopped cucumber and tomatoes, served with a glass of water (300ml). Participants were instructed to take as much time as they liked to consume as much or as little of any of the foods until they were comfortably full.

The macronutrient composition of the lunch foods, according to manufacturer labelling, is outlined in *Table 18*. An image of the lunch meal is displayed in *Figure 11*.

Table 18. Food items and nutritional composition of the *ad libitum* lunch

Food Item	Quantity (g)	Kcal/100g	Fat/100g	CHO/100g	Protein/100g
Uncle Ben's Tomato & Herb Risotto + Water	1,200	178	3.90	31.40	3.70
Sainsbury's Olive Oil	60	756	84	.50	.50
Sainsbury's cucumber (chopped)	115	10	.50	1.40	.70
Sainsbury's tomatoes (chopped)	115	20	.50	3.10	.70
Water	300	0	0	0	0

Figure 11. Image of the *ad libitum* lunch meal served to participants

6.3.3.4.4 *Ad libitum* dinner

Four hours (240-minutes) after lunch was served, dinner was served to participants. This is an appropriate delay between meal times and coincides with societal norms of an evening mealtime. Dinner consisted of vegetarian chilli with rice and a desert of chopped pineapple served *ad libitum,* with a glass of water (300ml). Participants were instructed that they have as much time to eat as much or as little as they would like until they reach a comfortable level of fullness. The macronutrient composition of the dinner foods, according to manufacturer labelling, is outlined in *Table 19* and an image of the dinner meal is displayed in *Figure 12*.

Table 19. Food items and nutritional composition of the *ad libitum* dinner

Food Item	Quantity (g)	Kcal/100g	Fat/100g	CHO/100g	Protein/100g
Uncle Ben’s Basmati Rice	245	153	1.60	30.90	3.30
Stagg Chilli Vegetable Garden	650	70	.50	14	3.50
Sainsbury's Olive Oil	45	756	84	.50	.50
Sainsbury's Medium Grated Cheddar Cheese	30	389	31.40	1.70	25
Sainsbury's Pineapple Pieces	230	58	.50	13.10	.50
Water	300	0	0	0	0

Figure 12. Image of the *ad libitum* dinner meal served to participants

6.3.3.4.5 Evening snack box

Upon consumption of the ad libitum dinner, participants were given a snack box to take away with them, containing a selection of pre-weighed foods. Participants were instructed to eat as much or as little as they liked of any of the foods until they went to sleep that night and to return all elements of the snack box, including empty packaging and partially-eaten foods, to the research unit the following morning at a pre-arranged time. This allowed 24-hour energy intake to be objectively measured across all conditions.

The macronutrient composition of the snack box foods, according to manufacturer labelling, is outlined in *Table 20* and an image of the foods included in the snack box is displayed in *Figure 13*.

Table 20. Food items and nutritional composition of the evening snack box items

Food Item	Quantity	Kcal/100g	Fat/100g	CHO/100g	Protein/100g
Yeo Valley Organic Greek Style Strawberry Yogurt	1 pot (120g)	76	0	11.80	6.50
Jordan’s Frusli Raisin & Hazelnut Cereal Bars	60g	399	12.20	64.30	5.80
Sainsbury’s Royal Gala Apples	2 apples	47	.50	12	.50
Sainsbury's Easy Peeler tangerine	2 tangerines	42	.50	8.70	.90
Tyrrel’s salted popcorn	40g	487	25.50	50.20	8.30
McVitie's Cheddars	60g	529	31.40	48.70	11.20
Sainsbury's Almonds	200g	595	49.90	9.10	21.20

Figure 13. Image of the foods included in the *ad libitum* snack box served to participants

6.3.4 Procedure

A flowchart depicting the full study timeline is displayed in *Figure 14*. A flowchart depicting the procedure on each of the probe days is depicted in *Figure 15*.

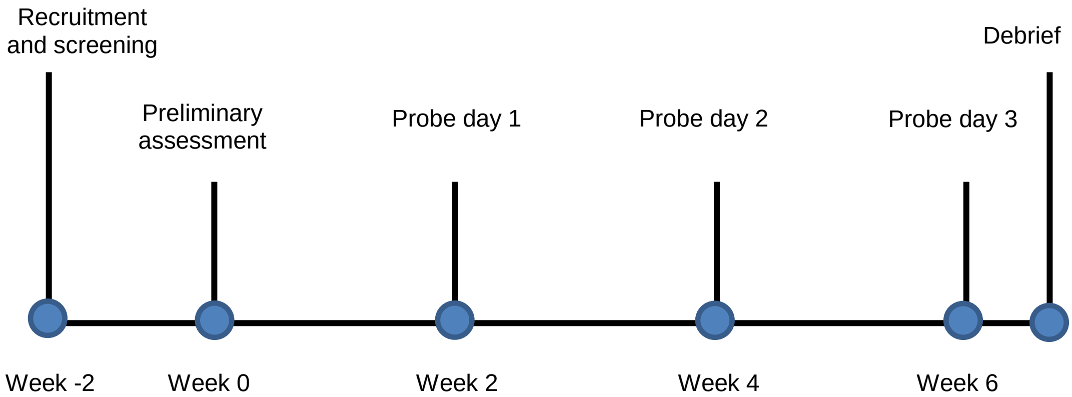

Figure 14. Flowchart depicting the full study timeline

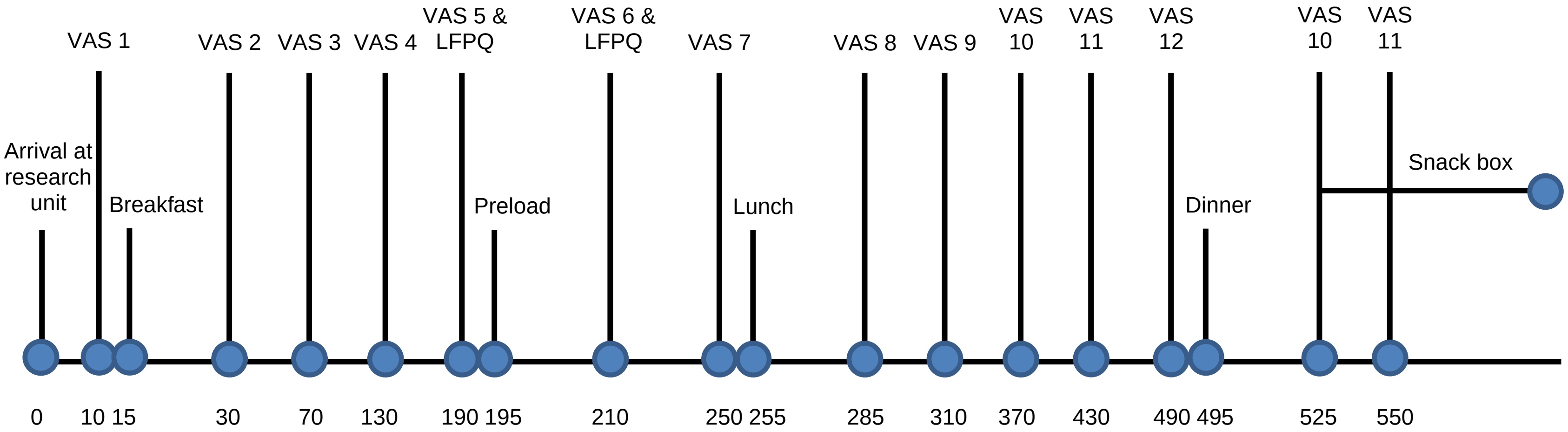

Figure 15. Flowchart depicting the probe day procedure

6.3.5 Data analysis plan

All data analysis was carried out using SPSS Statistics (IBM Corp., Armonk, NY) version 23. Results are reported as Mean (±SD) unless otherwise specified. All results were checked then converted into the appropriate units.

Differences in participant characteristics across the three YFAS groups were compared using one-way ANOVAs and significant effects were further explored using independent samples *t*-tests.

Using the visual analogue scales, the effect of YFAS group and preload condition on 24-h ratings of hunger, fullness, desire to eat and prospective consumption were assessed using a 3 (preload condition; HEP, LEP, NEP) x 14 (time point; TP) x 3 (HFA, MFA, LFA) mixed model ANOVA with YFAS group as the between-subjects variable. Where missing data points existed, the mean scores from the ratings immediately before and immediately after the missing points were taken (N=5). Where the missing data point fell on the last rating of the day (N=4), or where up to three simultaneous data points were missing (N=3), group means were used to replace the missing data. Where more than three simultaneous data points were missing (N=2), missing data was not replaced, as reflected in the sample sizes for these analyses.

Differences in energy intake across the YFAS groups and in response to the preloads were compared using a mixed model ANOVA with condition (HEP, LEP, NEP) as the within-subjects factor and YFAS group (HFA, MFA, LFA) as the between-subjects factor.

As this chapter addresses appetite control in terms of energy balance homoeostasis, energy intake and energy expenditure as contributors to total daily energy balance were analysed. Energy balance was calculated as TDEI minus TDEE and was compared across conditions and YFAS groups using a mixed model ANOVA with condition (HEP, LEP, NEP) as the within-subjects factor and YFAS group (HFA, MFA, LFA) as the between-subjects factor. A positive energy balance indicates an excess of energy intake compared to energy expenditure.

Where Maulchly's Test of Sphericity was significant (p <.05), the Greenhouse Geisser correction was applied to overcome the violation of sphericity. The Bonferroni correction for multiple comparisons was applied when post-hoc analyses revealed a significant effect. Effect sizes were calculated using partial eta squared (η_p^2) or Cohen's *d*, whereby the values for small, medium and large effects, respectively, for η_p^2 are .0099, .0588, and .1379 (Richardson, 2011), and for Cohen's *d* are .2, .5, and .8 (J. Cohen, 1988, 1992). For all analyses alpha was set at p <.05.

6.4 Results

6.4.1 Participant characteristics

The mean participant characteristics for each group are shown in *Table 21*. As expected by design, one-way ANOVAs confirmed no significant differences between YFAS groups in age, or BMI. There were no observed differences in body mass, fat mass, fat-free mass, body fat percentage, waist circumference or resting metabolic rate. As indicated by column '*p*', there was a significant difference in VO_{2Max} across YFAS groups ($F(2, 30) = 6.63$, p <.01), whereby independent samples *t*-tests revealed the HFA group had significantly lower cardiorespiratory fitness compared to LFA ($t(20) = 3.01$, p <.01, $d = 1.35$), and MFA ($t(21) = 3.00$, p <.01, $d = 1.31$).

Table 21. Demographic statistics for the LFA, MFA and HFA groups.

	LFA (N=10)	MFA (N=12)	HFA (N=12)	*p*
Age	22.40 (±3.34)	29.25 (±8.43)	26.42 (±7.99)	.10
Body mass (kg)	60.00 (±7.57)	60.93 (±7.45)	60.61 (±15.26)	.98
BMI (kg/m^2)	21.73 (±3.14)	22.14 (±2.74)	23.13 (±6.34)	.75
Fat mass (kg)	17.01 (±7.07)	16.93 (±4.92)	18.54 (±11.98)	.88
Fat-free mass (kg)	43.00 (±4.88)	43.99 (±5.30)	42.07 (±4.81)	.65
Body fat (%)	27.79 (±8.38)	27.56 (±5.64)	28.88 (±9.09)	.91

Waist (cm)	72.90 (±5.00)	76.47 (±6.75)	76.38 (±12.58)	.58
RMR (kcal)	1477.34 (±279.40)	1593.07 (±198.82)	1409.42 (±299.77)	.24
VO_{2Max} (ml/kg/min)	42.11 (±6.48)	40.73 (±4.30)[1]	33.76 (±6.49)	.004**

Note: Results are Mean (±SD). BMI: body mass index; RMR: resting metabolic rate. [1] N=11, * = p<.05, ** = p<.01, *** = p<.001.

6.4.1.1 Eating behaviour traits

One way ANOVAs were conducted to compare eating behaviour traits across YFAS groups, as indicated by column '*p*' (*Table 22*). By design, the three groups differed in YFAS 'symptom count' ($F(2, 31) = 114.87$, p <.001) whereby the HFA group had significantly higher scores compared to MFA ($t(22) = 8.35$, p <.001, $d = 3.55$) and LFA ($t(21) = 13.70$, p <.001, $d = 6.16$) and the MFA group had significantly higher YFAS scores compared to LFA ($t(20) = 8.66$, p <.001, $d = 3.86$). None of the sample met the dichotomous YFAS criteria for FA. The mean YFAS 'symptom count' across the whole sample was 1.88 (±1.74). YFAS scores between groups are displayed in *Table 22*.

There were significant differences between groups on scores on the Binge Eating Scale ($F(2, 31) = 9.11$, p <.01), TFEQ disinhibition subscale ($F(2, 31) = 5.81$, p <.01) and CoEQ positive mood subscale ($F(2, 31) = 4.36$, p <.05). Independent samples t-tests revealed that the HFA group had significantly higher scores on BES compared to the MFA ($t(22) = 2.59$, p <.05, $d = 1.11$) and LFA ($t(20) = 5.28$, p <.001, $d = 2.37$). HFA had significantly higher scores on TFEQ disinhibition compared to LFA ($t(20) = 4.41$, p <.001, $d = 1.98$). HFA had significantly lower CoEQ positive mood scores compared to MFA ($t(22) = 2.66$, p <.05, $d = 1.13$) and LFA ($t(20) = 2.80$, p <.05, $d = 1.25$), as displayed in *Table 22*.

Table 22. Eating behaviour traits in the LFA, MFA and HFA groups

	LFA (N=10)	MFA (N=12)	HFA (N=12)	*p*
YFAS ‘symptom count’	0 (±0)	1.42 (±.52)	3.92 (±.90)	.00***
BES	5.70 (±4.27)	9.42 (±7.85)	16.42 (±5.09)	.001**
TFEQ Restraint	8.20 (±3.88)	8.50 (±4.74)	9.92 (±4.36)	.61
TFEQ Disinhibition	4.30 (±2.21)	5.92 (±3.55)	8.17 (±1.90)	.007**
TFEQ Hunger	4.30 (±3.02)	4.75 (±3.86)	6.17 (±3.71)	.44
CoEQ Craving Control	64.10 (±21.94)	62.09 (±17.90)	48.69 (±15.70)	.11
CoEQ Craving Sweet	43.40 (±20.98)	43.95 (±23.23)	47.64 (±15.56)	.86
CoEQ Craving Savoury	42.10 (±21.80)	42.66 (±21.86)	57.75 (±9.88)	.09
CoEQ Positive Mood	62.78 (±11.28)	63.46 (±13.79)	51.17 (±8.20)	.02*

Note: Results are Mean (±SD). YFAS: Yale Food Addiction Scale; BES: Binge Eating Scale; TFEQ: Three-Factor Eating Questionnaire; CoEQ: Control of Eating Questionnaire.
* = p<.05, ** = p<.01, *** = p<.001.

6.4.1.2 Habitual physical activity

The physical activity (PA) characteristics between YFAS groups were compared and displayed in *Table 23*. One way ANOVAs were conducted to compare PA across groups, as indicated by column ‘*p*’. Differences in physical activity level (PAL) between groups neared significance ($F(2, 29) = 3.28$, p =.05), therefore independent samples *t*-tests were conducted to compare groups. The results revealed that PAL in HFA was significantly lower compared to LFA ($t(19) = 2.30$, p <.05, d = 1.05). Significant differences in minutes of moderate-to-vigorous physical activity (MVPA) between YFAS groups were found ($F(2, 29) = 4.26$, p <.05). Independent samples *t*-tests revealed that the

HFA group had significantly fewer minutes of MVPA compared to LFA ($t(19) = 2.70$, $p < .05$, $d = 1.24$).

Table 23. Habitual physical activity in the LFA, MFA and HFA groups

	LFA (N=10)	MFA (N=11)	HFA (N=11)	*p*
SW Wear Time	1420.32 (±6.91)	1417.37 (±13.59)	1414.53 (±16.16)	.60
TDEE (kcal)	2282.60 (±373.41)	2132.91 (±230.34)	2041.71 (±264.38)	.18
Light PA	245.56 (±55.33)	207.19 (±51.53)	237.30 (±85.50)	.38
MVPA	135.31 (±54.22)	107.30 (±36.39)	79.45 (±40.05)	.02*
SED	613.50 (±86.92)	677.71 (±78.75)	664.82 (±106.48)	.26
PAL	1.65 (±.18)	1.56 (±.10)	1.49 (±.14)	.05

Note: Results are Mean (±SD). SW: SenseWear Armband; TDEE: total daily energy expenditure; PA: physical activity; MVPA: moderate-to-vigorous physical activity; SED: sedentary behaviour; PAL: physical activity level.
* = $p<.05$, ** = $p<.01$, *** = $p<.001$.

6.4.2 Appetite ratings

Repeated measures ANOVAs were conducted to compare ratings of hunger, fullness, desire to eat and prospective consumption across the meal days. Due to missing data, the following analyses contained 8 participants in the LFA group and 12 participants in the MFA and HFA groups.

6.4.2.1 Hunger

There were no significant differences in baseline (time point; TP 1) hunger ratings between preloads (p =.37), or groups (p =.68), nor a significant interaction between preload and YFAS group (p = .64).

There was no significant main effect of YFAS group (*p* =.77), or significant interactions between YFAS group and either preload or time on hunger ratings. Throughout the day a significant main effect of preload on hunger ratings was found (F(1.64, 47.54) = 24.37, *p* <.001, η_p^2 = .46), whereby hunger ratings were higher in the NEP condition (M: 33.52) compared to the HEP (M: 21.65) and LEP (M: 26.08) conditions (both *p* <.01), and higher in the LEP compared to HEP (*p* <.01) conditions. There was a significant main effect of time on hunger ratings (F(5.13, 148.87) = 77.21, *p* <.001, η_p^2 = .73) and a significant interaction between preload and time (F(11.03, 319.77) = 13.53, *p* <.001, η_p^2 = .32).

Post-hoc comparisons revealed significantly higher hunger ratings in the NEP condition relative to the HEP and LEP conditions immediately after the preload (TP 6; *p* <.001) and immediately before lunch (TP 7; *p* <.001). Hunger ratings were higher post-lunch (TP 8) in the NEP condition compared to HEP (*p* <.05). HEP continued to significantly suppress hunger compared to LEP and NEP (all *p* <.05) throughout the afternoon until pre-dinner (TP 12), whereby hunger was suppressed in HEP compared to LEP (*p* <.05). No differences in hunger ratings between preloads were seen post-dinner (TP 13), but HEP suppressed hunger to a greater extent than LEP (*p* <.05) 1-h post-dinner (TP 14). These results are depicted in *Figure 16*. As the interest of this thesis is differences across YFAS groups, the figure displays the ratings collapsed across preload conditions.

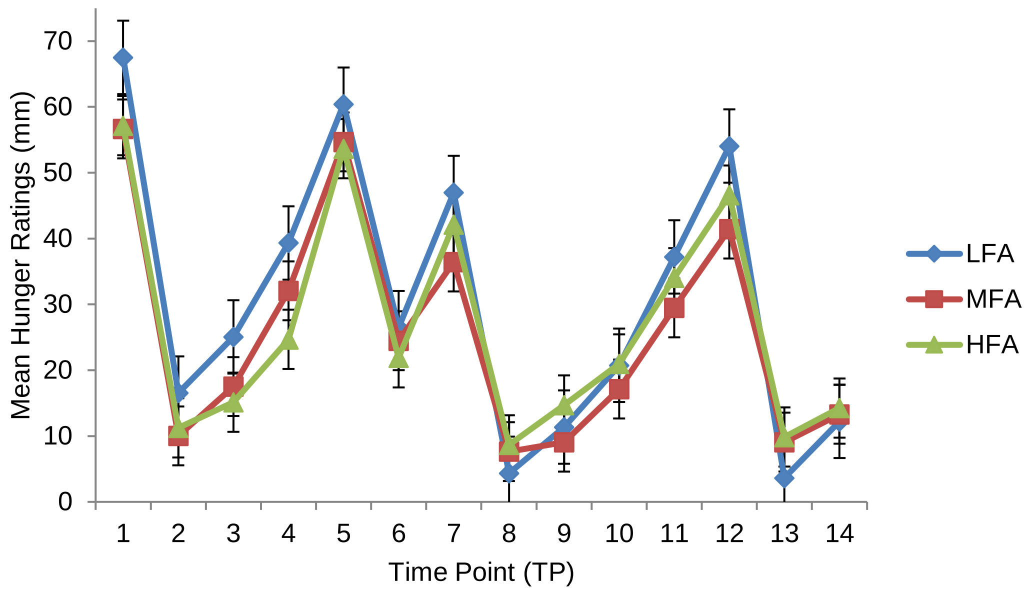

Figure 16. Hunger ratings across the day for each YFAS group, collapsed across conditions. Note: lines denote Standard Error

6.4.2.2 Fullness

There were no significant differences in baseline (TP 1) fullness ratings between preloads (p =.94), nor a significant main effect of YFAS group (p =.20), but there was a significant interaction between preload and YFAS group on baseline hunger ($F(4, 58) = 2.92$, p <.05, $\eta_p^2 = .17$). However, post-hoc comparisons revealed no specific significant differences in hunger ratings across preloads and YFAS groups (all p >.06).

There was no main effect of YFAS group (p =.22) or significant interactions between YFAS group and either preload (p =.81) or time (p =.25) on fullness ratings. Throughout the day a significant main effect of preload on fullness ratings was found ($F(2, 58) = 16.66$, p <.001, $\eta_p^2 = .37$), whereby fullness ratings were higher in the HEP condition (M: 60.82) compared to the LEP (M: 56.06; p <.05) and NEP (M: 48.65; p <.001) conditions, and higher in the LEP compared to NEP (p <.05) conditions. There was a significant main effect of time on fullness ratings ($F(7.07, 205.12) = 102.30$, p <.001, $\eta_p^2 = .78$) and a significant interaction between preload and time ($F(10.46, 303.38) = 9.14$, p <.001, $\eta_p^2 = .24$).

Post-hoc comparisons revealed significantly higher fullness ratings in the HEP and LEP conditions compared to NEP post-preload (TP 6; *p* <.001) and pre-lunch (TP 7; *p* <.001), and significantly greater fullness in HEP compared to NEP post-lunch (TP 8; *p* <.05). Fullness was greater in HEP compared to LEP and NEP 1-h post-lunch (TP 9; *p* <.01) and greater than NEP 2-h post-lunch (TP 10; *p* <.01), and 3-h post-lunch (TP 11; *p* <.05). Post-dinner (TP 13), fullness was greater in LEP compared to NEP (*p* <.05). These results are depicted in *Figure 17.* As the interest of this thesis is differences across YFAS groups, the figure displays the ratings collapsed across preload conditions.

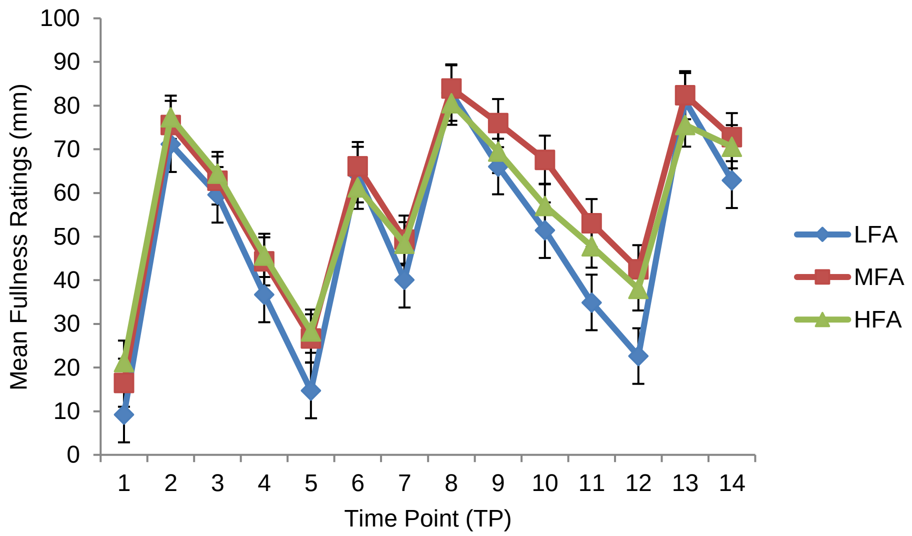

Figure 17. Fullness ratings across the day for each YFAS group, collapsed across conditions. Note: lines denote Standard Error

6.4.2.3 Desire to eat

There were no significant differences in baseline (TP 1) desire to eat ratings between preloads (*p* =.14), no significant main effect of YFAS group (*p* =.76), nor a significant interaction between preload and YFAS group (*p* =.12).

There was no main effect of YFAS group (*p* =.98) or a significant interactions between YFAS group and preload (*p* =.54) or time (*p* =.39) on desire to eat. Throughout the day, there was a significant main effect of preload on desire to eat ($F(2, 58) = 32.10$, $p < .001$, $\eta_p^2 = .53$), whereby desire to eat was significantly higher in the NEP condition (M: 37.15) compared to the HEP (M: 23.74; *p*

<.001) and LEP (M: 27.13; p <.001) conditions. There was a significant main effect of time on desire to eat ($F(5.53, 160.33) = 72.64$, p <.001, η_p^2 =.72) and a significant interaction between preload and time ($F(10.43, 302.38) = 9.19$, p <.001, η_p^2 = .24).

Post-hoc comparisons revealed significantly higher desire to eat in NEP compared to HEP and LEP post-preload (TP 6; p <.001) and pre-lunch (TP 7; p <.001) and compared to HEP post-lunch (TP 8; p <.05). Desire to eat was suppressed in HEP 1-h post lunch (TP 9) compared to LEP and NEP (p <.01), 2-h post lunch (TP 10) compared to NEP (p <.01), 3-h post lunch (TP 11) compared to LEP (p <.05) and NEP (p <.01), pre-dinner (TP 12) compared to NEP (p <.05), and 1-h post-dinner (TP 14) compared to NEP (p <.01). Desire to eat was also suppressed at TP 14 in LEP compared to NEP (p <.05). These results are depicted in *Figure 18*. As the interest of this thesis is differences across YFAS groups, the figure displays the ratings collapsed across preload conditions.

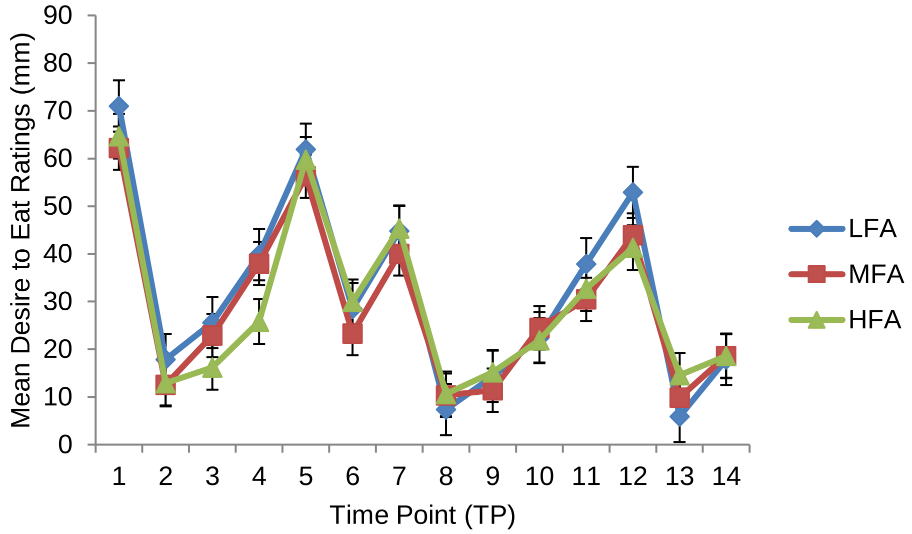

Figure 18. Desire to Eat ratings across the day for each YFAS group, collapsed across conditions. Note: lines denote Standard Error

6.4.2.4 Prospective consumption

There were no significant differences in baseline (TP 1) prospective consumption ratings between preloads (p =.62), or a significant main effect of

YFAS group (*p* =.38). However, there was a significant interaction between preload and YFAS group in baseline prospective consumption ratings (F(4, 58) = 3.11, *p* <.05, η_p^2 = .18), whereby, in the MFA group, prospective consumption ratings were significantly higher in the HEP (M: 58.25) compared to LED (M: 40.00) preload (*p* <.05).

There was no main effect of YFAS group (*p* =.93) nor significant interactions between YFAS group and preload (*p* =.75) or time (*p* =.26) on prospective consumption ratings. Across the day, a significant main effect of preload on prospective consumption was found (F(1.65, 47.89) = 17.82, *p* <.001, η_p^2 = .38), whereby prospective consumption was higher in the NEP condition (M: 29.44) compared to the HEP (M: 20.00; *p* <.001) and LEP (M: 22.98; *p* <.01) conditions. There was a significant main effect of time on prospective consumption (F(5.29, 153.54) = 83.77, *p* <.001, η_p^2 = .74) and a significant interaction between preload and time (F(10.70, 310.30) = 11.23, *p* <.001, η_p^2 = .28).

Post-hoc comparisons revealed significantly higher prospective consumption ratings in NEP compared to HEP and LEP post preload (TP 6; *p* <.001) and pre-lunch (TP 7; *p* <.001). 1-h post-lunch (TP 9) and 2-h post-lunch (TP 10), prospective consumption was significantly more suppressed in HEP compared to NEP (*p* <.05). HEP produced significantly lower prospective consumption ratings 3-h post-lunch (TP 11) compared to LEP (p <.05) and pre-dinner (TP 12) compared to LEP and NEP (*p* <.05), and 1-h post-dinner (TP 14) compared to NEP (*p* <.05). These results are depicted in *Figure 19*. As the interest of this thesis is differences across YFAS groups, the figure displays the ratings collapsed across preload conditions.

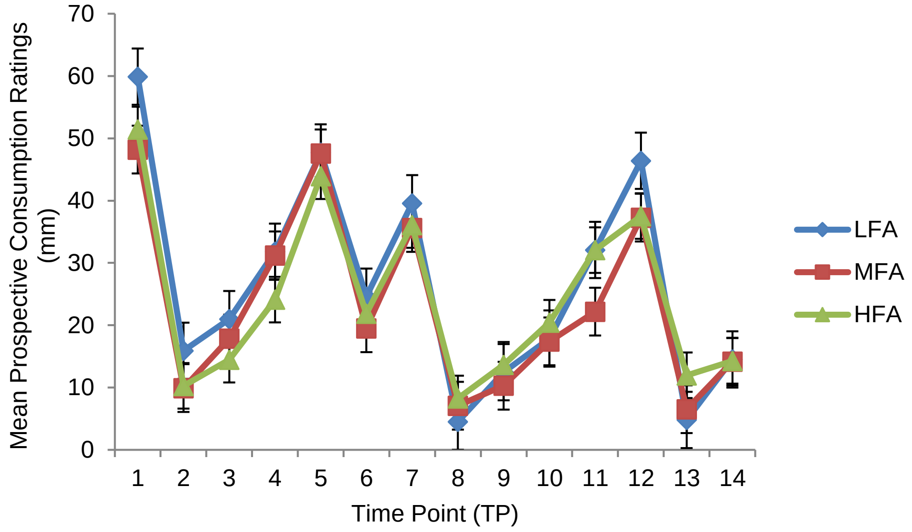

Figure 19. Prospective Consumption ratings across the day for each YFAS group, collapsed across conditions. Note: lines denote Standard Error

6.4.3 Meal consumption

6.4.3.1 Lunch consumption

There was a significant main effect of preload condition on lunch consumption ($F(2, 62) = 34.29$, $p < .001$, $\eta_p^2 = .53$), with subjects consuming significantly less energy at lunch in the HEP condition (M: 418.89 kcal) compared to LEP (M: 520.80; $p < .01$) and NEP (M: 737.40; $p < .001$), and in LEP compared to NEP ($p < .001$). These results are shown in *Figure 20*. However, there was no main effect of YFAS group ($p = .32$), nor an interaction between YFAS group and lunch EI ($p = .78$).

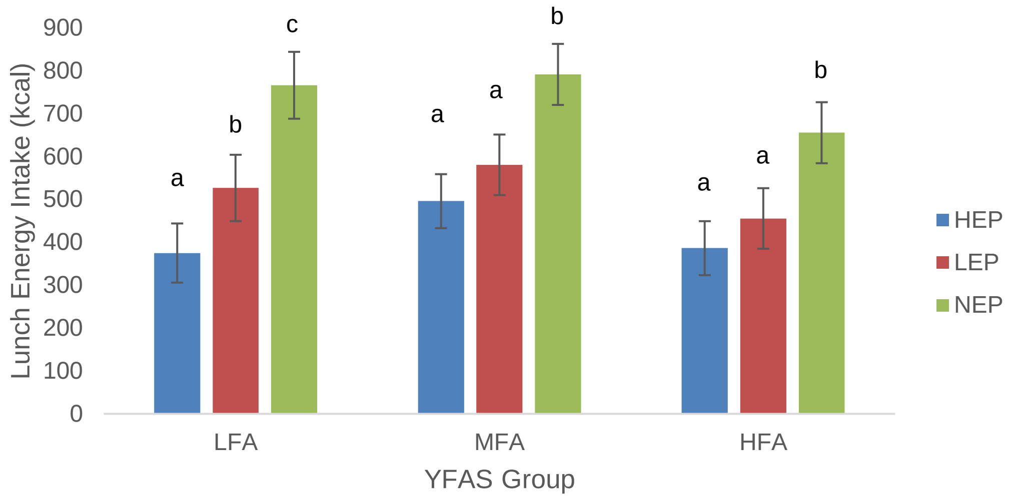

Figure 20. Energy intake at lunch following the high energy (HEP), low energy (LEP) and no energy (NEP) preloads across YFAS groups. Note: lines denote standard error. Unalike letters indicate significant difference (per group).

6.4.3.2 Dinner consumption

There was no main effect of preload condition on EI at dinner (*p* =.19), no main effect of YFAS group (*p* =.24), nor an interaction between preload and YFAS group (*p* =.30), as demonstrated in *Figure 21*.

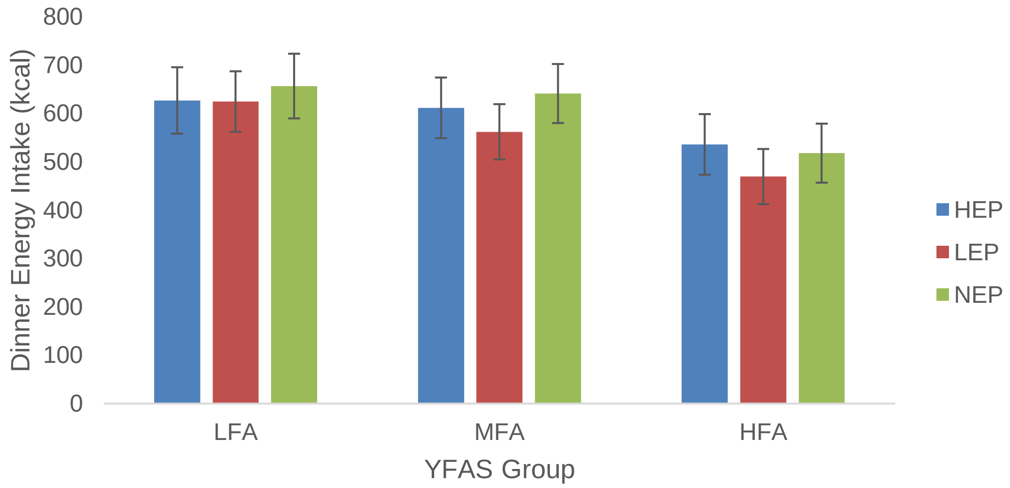

Figure 21. Energy intake at dinner following the high energy (HEP), low energy (LEP) and no energy (NEP) preloads across YFAS groups. Note: lines denote standard error

6.4.3.3 Snack box consumption

There was no main effect of preload condition on EI from the snack box (*p* = .10), no of YFAS group (*p* =.60). There was no interaction between preload and YFAS group (*p* = .32), as demonstrated in *Figure 22*.

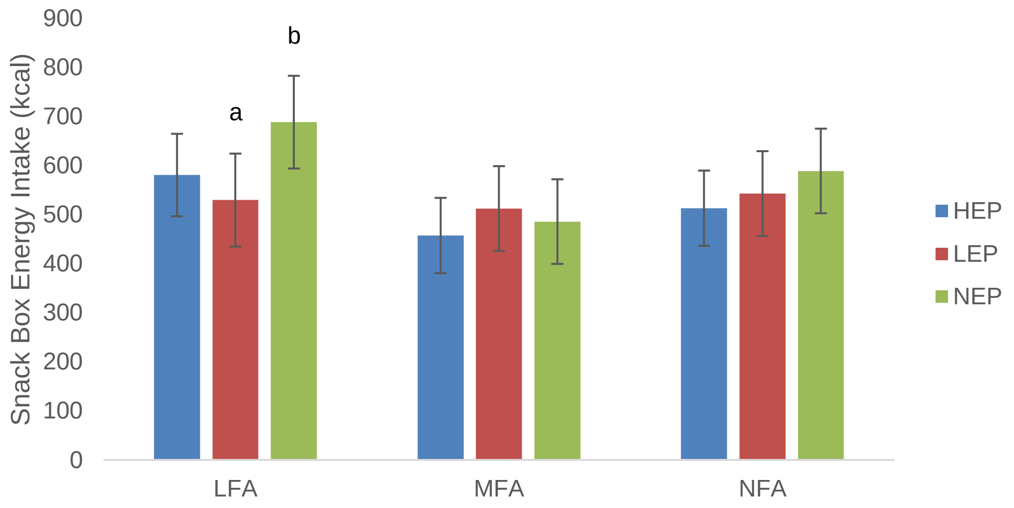

Figure 22. Energy intake from snack box following the high energy (HEP), low energy (LEP) and no energy (NEP) preloads across YFAS groups. Note: lines denote standard error. Unalike letters indicate significant difference.

6.4.3.4 Total daily energy intake

There was a significant main effect of preload condition on total daily EI (F(2, 62) = 13.22, *p* <.001, η_p^2 = .30), with participants consuming significantly more in HEP (M: 2584.32) compared to LEP (M: 2226.84, *p* <.001) and NEP (M: 2299.65, *p*<.01). There was no main effect of YFAS group (*p* =.36), nor an interaction between YFAS group and preload on total daily EI (*p* = .81). These results are demonstrated in *Figure 23*.

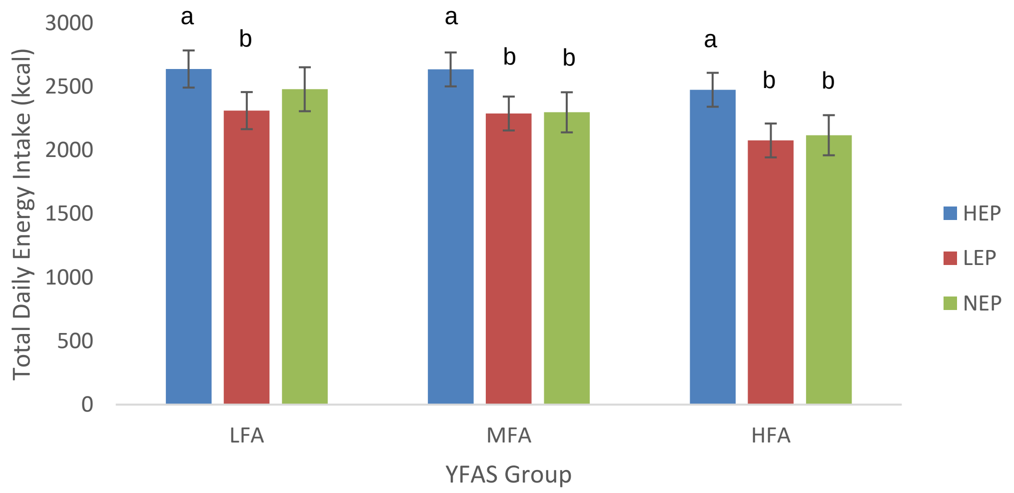

Figure 23. Total daily energy intake in the high energy (HEP), low energy (LEP) and no energy (NEP) preload conditions across YFAS groups. Note: lines denote standard error. Unalike letters indicate significant difference (per group).

6.4.4 Energy Balance

The mixed model ANOVA revealed a significant effect of condition on energy balance (F(2, 62) = 9.64, p <.01, η_p^2 = .24). Post hoc analyses revealed that energy balance was significantly higher (positive energy balance) in the HEP condition (M: 612.19) compared to LEP (M: 185.51, p <.001) and NEP (M: 277.32, p <.05). There was no significant interaction between condition and YFAS group, demonstrating that the greatest extent of passive overconsumption during the HEP meal day, compared to other conditions, across all participants, regardless of YFAS group. These results are demonstrated in *Figure 24*.

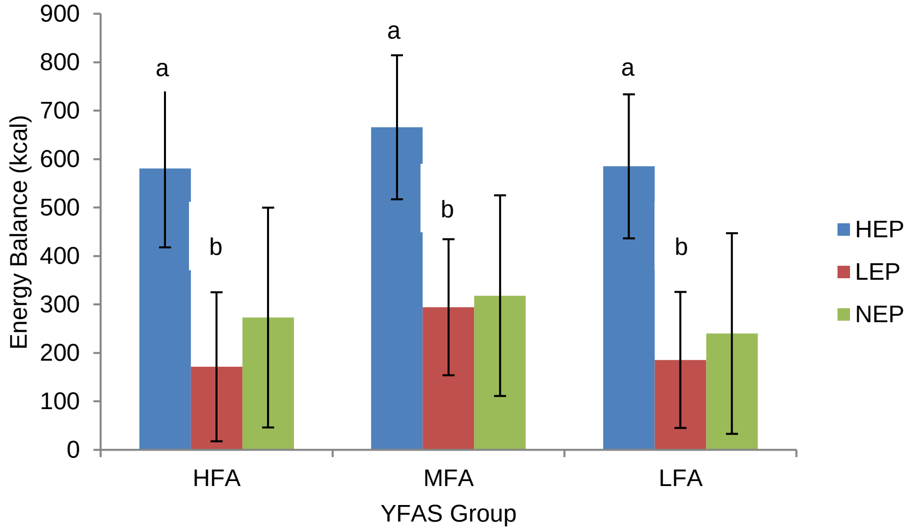

Figure 24. Energy balance across the day in the high energy (HEP), low energy (LEP) and no energy (NEP) conditions across YFAS groups. Note: lines denote standard error. Unalike letters indicate significant difference. A positive energy balance indicates a greater total daily energy intake than total daily energy expenditure.

6.5 Discussion

The present chapter aimed to explore so-called FA within an energy balance framework. The chapter assessed the habitual physical activity and homeostatic appetite control of 34 female participants differing in scores on the YFAS in response to a covertly manipulated preload paradigm. Participants were categorised according to their score on the YFAS as either low (LFA), moderate (MFA) or high (HFA) and matched for age and BMI across groups. Participant characteristics, including objectively measured physical activity and habitual energy expenditure were compared across groups, followed by analysis of 24-hour appetite responses and energy intake in response to a high energy (HEP), low energy (LEP) or no energy (NEP) preload. In order to limit the hedonic drivers of EI, and therefore dissociate homeostatic factors, the test meals were designed to minimise highly palatable foods.

Analysis of the sample characteristics revealed that the HFA group displayed a greater tendency towards binge eating and a less positive mood compared to MFA and LFA groups, as well as a greater disinhibition compared to the LFA group. Such results are similar to the correlations reported in Chapter 4, and demonstrate an increased susceptibility towards problematic eating behaviours alongside YFAS scores. However, as noted in Chapter 4, such associations are to be expected as Vainik et al. (2015) found that many eating behaviour scales seem to represent a common underlying trait which they labelled ‘uncontrolled eating’. Whether these problematic eating behaviour traits were reflected in physiological characteristics and energy intake behaviours was therefore examined.

No differences in anthropometrics or physiological characteristics across YFAS groups were discovered, except for cardiorespiratory fitness, whereby the HFA group displayed lower aerobic capacity compared to the MFA and LFA groups. These results were further supported through comparison of the habitual physical activity level of the sample. It was revealed that the HFA group was less physically active and participated in significantly fewer minutes of moderate-to-vigorous physical activity compared to the LFA group. Based on current knowledge, this study is the first of its kind to objectively measure habitual physical activity levels as a function of YFAS score. Given the detrimental effects of low levels of physical activity on appetite control (Blundell, 2011; Stubbs, Hughes, Johnstone, Horgan, et al., 2004), individuals with low PA levels are at particular risk for overconsumption and a positive energy balance. This, coupled with the compulsive eating behaviour traits identified in the HFA group, may dispose this group towards increasing adiposity. However, these results should not be used to support the idea that low levels of physical activity are characteristic of a possible food addiction phenotype. Rather, individuals who display maladaptive eating behaviour traits are also likely to engage in lower levels of PA, and these may demonstrate a clustering of unhealthy behaviours. Individuals presenting such clustering may require interventions that target multiple health behaviours in order to improve their satiety responsiveness.

Unexpectedly, however, such differences in PA levels did not translate into differences in physiological characteristics of the sample. The sample was matched for BMI across groups, therefore no differences in BMI or body mass existed between groups, by design. However, no significant differences in fat mass, fat-free mass, percentage body fat or RMR between groups were discovered. However, the data did suggest a trend towards increasing body fat and decreasing fat-free mass with increasing YFAS score, likely due to the lower levels of physical activity in the HFA group (Myers, Gibbons, Finlayson, & Blundell, 2016). A larger sample size may be required in order to detect any differences in body composition at a given BMI as a function of YFAS score.

These results are in contrast with a recent study by Pursey, Gearhardt, and Burrows (2016) who investigated the relationship between YFAS responses and adiposity in young females. These authors reported that YFAS 'symptom count' predicted higher visceral adiposity when controlling for age, and that YFAS score was associated with increasing BMI and percentage body fat. Similarly, Pedram et al. (2013) reported that 'food addicts', as classified by the YFAS, had 8.2% greater body fat and 8.5% more trunk fat compared to those who did not meet the YFAS criteria. However, in a sample of overweight or obese adults, Pedram and Sun (2014) reported no differences in body composition between individuals who met the YFAS criteria for FA and those who did not. The discrepancy of results in the present chapter may be due to controlling for BMI by design. For example, when BMI is kept constant in an obese state across subjects, as in the study by Pedram and Sun (2014), there are no differences in body composition, yet when BMI varies across subjects there is an increase in visceral fat in high YFAS individuals (Pursey et al., 2016).

As low levels of PA have been reported to impair appetite control (S. J. Long et al., 2002; Murgatroyd, Goldberg, Leahy, Gilsenan, & Prentice, 1999; Myers et al., 2016) and promote overconsumption (Beaulieu, Hopkins, Blundell, & Finlayson, 2016; Mayer et al., 1956; Shook et al., 2015), it could be assumed that, in the present study, the HFA group would display impaired homeostatic appetite control due to their lower levels of PA. However, the results revealed no significant differences in energy intake at lunch, dinner, snack box or total daily EI across YFAS groups. Rather, there was an effect of the preload on lunch intake, whereby, as expected given its increased energy content, the HEP condition suppressed EI to a greater extent compared to LEP and NEP. These findings demonstrate sensitivity of the preload manipulation across all participants and an acute compensatory effect in the HEP condition. However, across the whole day, participants ate significantly more in the HEP compared to LEP and NEP conditions, regardless of YFAS group, demonstrating that the reduction in EI at lunch following HEP was not sufficient to accurately compensate for the increase in EI contained in the HEP condition across the rest of the day. This overconsumption in the HEP condition may be attributed to the increase in energy density (ED) of this preload, which has been demonstrated to play an important role in passive overconsumption (Kral & Rolls, 2004; Stubbs, Johnstone, O'Reilly, Barton, & Reid, 1998). Given the availability of energy dense foods in the modern environment, reducing intake of energy dense foods is an important strategy to avoid overconsumption. Such findings support those of Chapter 5, whereby high energy dense foods were revealed to be perceived as more problematic and having 'addictive potential', suggesting both a hedonic and homeostatic dysfunction associated with increasing ED. However, as there were no differences between YFAS groups on the lack of EC in the HEP condition, these results suggest that individuals with increasing YFAS scores do not present any greater susceptibility towards overconsumption of energy dense foods, compared to low YFAS-scorers.

These findings were further supported by ratings of appetite sensations, whereby a main effect of preload condition was discovered for ratings of hunger, fullness, desire to eat and prospective consumption. However, YFAS scores had no impact on these ratings. During the post-preload phase, hunger, desire to eat and prospective consumption ratings were consistently suppressed and fullness was significantly promoted in the HEP condition compared to LEP and NEP, demonstrating a satiating effect of the high energy preload in all YFAS groups. Support by previous research (for example, Rolls, Roe, & Meengs, 2004) has been mixed, where some studies have reported no differences in appetite ratings following preload differing in energy content (Rolls et al., 1999). The differing sizes and timings of preloads given to participants across studies must be considered here (Jakubowicz, Froy, Wainstein, & Boaz, 2012; Porrini et al., 1997; Veldhorst et al., 2009) as a possible explanation for the mixed support for the findings reported in this chapter. Furthermore, despite the lower sensations of hunger, desire to eat and prospective consumption in the HEP condition pre-dinner, no differences in EI at the dinner meal were observed.

Differences between YFAS groups were, however, uncovered in eating behaviour traits. The HFA group reported significantly higher levels of binge eating and a more negative mood compared to the MFA and LFA groups, and greater disinhibition compared to the LFA group. Such results are supported by significant correlations between the YFAS ‘symptom count’ and these measures of eating behaviours reported in Chapter 4. These findings suggest that those individuals scoring highly on the YFAS may display problematic eating behaviours, yet the results of the present chapter suggest that such behaviours do not translate into food intake under laboratory conditions. Nevertheless, the present study was designed to reduce hedonic stimulation from those foods which are considered highly palatable (such as high fat and high carbohydrate foods; see Chapter 5 for a detailed discussion on this topic). It is therefore possible that so-called food addicts may only present impaired eating behaviours towards hedonically-rewarding, highly palatable foods, which may contribute to the lack of differences in energy intake across YFAS groups in the present study. Hedonic drivers of appetite in relation to YFAS score are discussed in detail in Chapter 7.

6.5.1 Limitations

Although the present study aimed to overcome the lack of research into energy balance in relation to the YFAS, the laboratory-based design limits the generalisability of these results to free-living human eating behaviour (Blundell et al., 2010). That notwithstanding, the preload paradigm is one of the most widely-validated techniques to measure satiety, and the covert manipulation and single-blind nature of the preloads included in the present study were sensitive to differences in appetite regulation, as evidenced by the differing hunger profiles and energy intake across conditions (Blundell & Stubbs, 2003). The limited sample size in the present study should be addressed in future research in order to improve the power of the analyses. Furthermore, although the sample included a wide range of YFAS scores, no participants met the dichotomous YFAS criteria for FA. Future research could compare those individuals who report significant distress as a result of overeating, in addition to endorsing at least 3 YFAS criteria, with those with lower endorsement of YFAS criteria.

6.5.2 Conclusions

The present chapter is the first of its kind to objectively measure 24-h energy intake, energy expenditure and habitual physical activity in relation to FA, as measured by the YFAS. The results revealed that those individuals reporting high scores on the YFAS possess problematic eating behaviour traits (trait binge eating, disinhibition), a less positive mood, and lower levels of habitual physical activity compared to those with lower scores. However, when controlling for BMI, an increasing YFAS score was not found to be related to a worsening homeostatic control over eating, as demonstrated by a similar satiety response to a covertly manipulated preload design across YFAS groups. The whole sample displayed passive overconsumption following the high energy preload, as revealed by a relative increase in energy intake over the whole day, compared to the low- and no-energy conditions, as a result of the covert manipulation of the energy density of the preloads, which has been reported to prompt overconsumption (Bell et al., 1998; Kral, Roe, & Rolls, 2002; Stubbs et al., 1998; Stubbs & Whybrow, 2004).

To conclude, when hedonic drivers of food consumption are minimised, as in this chapter, the results suggest that YFAS scores are not associated with altered or dysregulated homeostatic appetite control. However this leaves open the possibility that FA is a function of the hedonic system. Therefore a test of hedonic appetite is needed to complement these findings. Nevertheless, individuals should reduce their consumption of energy dense foods and increase PA as a strategy maintain a healthy energy balance, regardless of YFAS score.

Summary

- Individuals with high scores on the YFAS displayed greater levels of trait binge eating and disinhibition and a less positive mood, compared to low-scorers.
- High YFAS-scoring individuals presented lower aerobic fitness, a lower physical activity level and fewer minutes of moderate-to-vigorous physical activity compared to low-scorers.
- In an objective laboratory assay of eating behaviour, no differences in homeostatic control of appetite was revealed between YFAS groups, as all participants reduced consumption at lunch to a greater extent following the high-energy preload, compared to the low- or no-energy preload.
- Individuals with high YFAS scores do not display dysregulated homeostatic appetite control and therefore a test of hedonic eating behaviour is needed to elucidate whether FA is a condition of the hedonic system.

Chapter 7

Investigation of hedonic processes in individuals varying in scores on the Yale Food Addiction Scale: the role of liking and wanting

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Aims

- To explore the influence of YFAS score on food choice.
- To explore whether these food choices extend beyond the acute laboratory setting and relate to free-living eating behaviour.
- To explore the influence of YFAS score on food hedonics and preference (explicit liking, explicit wanting and implicit wanting towards high and low fat, sweet and savoury foods), in hungry and satiated states.

7.1 Abstract

Background: The proposed overlaps between overeating and drug addiction suggest that highly palatable foods, particularly those high in fat, may be implicated in 'addictive'-like eating, represented by enhanced food wanting, rather than liking, in individuals classified as 'food addicts', according to the Yale Food Addiction Scale (YFAS). Therefore, this chapter aimed to: 1) explore any differences in energy and macronutrient intake, hedonic responsiveness and craving, using validated laboratory and free-living food intake methodologies across tertiles of YFAS scores. It was hypothesised that subjects in the highest tertile of YFAS scores would consume more energy and fat compared to low-scorers, display increased explicit and implicit wanting for high fat foods and crave foods more strongly.

Method: 34 female participants (age: 25.24 ± 5.69, BMI: 27.45 ± 5.46) were grouped according to their YFAS 'symptom count' using a tertile split, to form a high (HFA; YFAS score = ≥3; N=10), moderate (MFA; YFAS score = 2; N=9) and low (LFA; YFAS score = 1; N=15) YFAS group. EI was assessed over 48-hours using a laboratory-based test-meal (TM) methodology and a free-living dietary recall (DR) assessment. TM consisted of *ad libitum* breakfast, lunch, afternoon snacks and dinner meals as well as a preliminary assessment (body composition). Subjective ratings of appetite sensations were obtained throughout the TM test day and hedonic liking and wanting were assessed pre- and post-lunch consumption (Leeds Food Preference Questionnaire). DR utilised the Automated Multiple Pass Method (AMPM) to recall all foods and beverages consumed the day after TM, and eating behaviour questionnaires, to measure FA, trait binge eating and food cravings, were completed at the end of the DR session.

Results: Analysis of the sample characteristics revealed that the HFA group had significantly higher binge eating, restraint, disinhibition, hunger and craving for sweet foods compared to LFA or MFA. In the TM session, the MFA group consumed more energy at lunch compared to HFA and LFA, the HFA group consumed more energy at dinner compared to MFA and LFA, whilst both HFA and MFA consumed more energy from the afternoon snacks compared to LFA. HFA consumed significantly more energy from high fat sweet (HFSW) snacks compared to MFA and LFA and the other food categories. In the DR session, no differences in EI at breakfast, lunch or dinner were revealed between groups, yet the HFA group consumed significantly more energy from snack

foods compared to MFA and LFA. Analysis of food hedonics revealed that HFA displayed enhanced explicit liking and implicit wanting for HFSW foods according to the LFPQ.

Conclusions: Individuals in the highest tertile of YFAS ‘symptom count’ scores display increased preference towards, cravings for, and consumption of high fat and sweet foods and snack foods. However, this pattern of overconsumption appears to be driven by both enhanced wanting and liking in individuals with high scores on the YFAS. A rational interpretation is that individuals scoring highly on the YFAS simply possess strong preferences towards palatable foods, rather than demonstrating ‘addictive’ behaviours.

7.2 Introduction

As discussed in Chapter 6, empirical literature exploring the actual eating behaviours of individuals who vary in their degree of so-called “food addiction” is lacking. Rather, the self-report Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009b) attempts to operationalise so-called food addiction symptomatology according to the diagnostic criteria for substance dependence, as described in the DSM-IV-TR (American Psychiatric Association, 2000), adjusting these criteria to eating behaviour (EB). In order to address this gap in the literature, Chapter 6 explored the homeostatic control of appetite in 34 females ranging in scores on the YFAS. The results indicated no impairments in homeostatic appetite control as a function of YFAS symptomatology, with all participants decreasing energy intake (EI) at an *ad libitum* lunch meal to a greater degree following a high energy preload, compared to a low- or no-energy preload. Whilst these are interesting and novel findings, it should be considered that human appetite is heavily influenced by hedonic processes of eating behaviour, in addition to homeostatic functions, and a key proposition underlying the FA hypothesis is that it is a disorder of the hedonic system (Davis, Levitan, Carter, Kaplan, & Kennedy, 2012; Davis & Loxton, 2014).

7.2.1 Hedonic processes of liking and wanting

Hedonic processes are those concerned with the rewarding value and response to food, driven by expectation and previous experience of the pleasure associated with eating. Hedonically-driven eating can override homeostatic signals and result in eating beyond biological and metabolic need (Blundell & Finlayson, 2011; Levin, 2006), especially given the abundance of highly palatable and easily accessible foods in the modern food environment (Gearhardt, Grilo, et al., 2011; J. O. Hill & Peters, 1998). Behavioural neuroscience research has led to the proposition that two distinct but inter-linked processes may be involved in the hedonic system of appetite control: wanting and liking (Berridge, 1996; Berridge & Robinson, 2003; Finlayson et al., 2007b). Wanting refers to the motivational salience attributed to a stimulus, and is often used synonymously with craving, whilst liking refers to the subjective pleasure derived from the stimulus. Although rewards that are liked are also generally wanted (Berridge & Robinson, 2003), evidence suggests that liking and wanting are underpinned by separable neural mechanisms and can therefore be dissociated (Berridge, 1996). Namely, liking is mediated by opioid neurotransmitter systems and wanting is mediated through dopamine (DA) systems (Berridge, 1996; Davis et al., 2009), permitting neurochemical and possibly functional dissociations to occur.

Anecdotal evidence for a dissociation between wanting and liking in everyday life comes from the reports of people with substance dependence disorders, who continue to crave or want their drug of choice even though they report no longer liking it (T. E. Robinson & Berridge, 1993). Sustained administration of addictive drugs is thought to cause sensitisation of the mesocorticolimbic DA system, leading to increased incentive salience attributed to drug taking and its associated cues (i.e., wanting), independently of any adaptations in the neural opioid pathways which mediate liking (Koob & Le Moal, 1997). This suggestion is supported by research in rodents whereby activation of the DA system can amplify behaviours consistent with wanting without affecting liking responses (Berridge, Robinson, & Aldridge, 2009). For example, rats with a specific genetic mutation which increases extracellular DA were reported to display greater wanting towards a sweet reward (Cagniard, Balsam, Brunner, & Zhuang, 2006), measured by intake, without increasing liking towards a sucrose taste (expressed through lip licking or rhythmic tongue protrusions, Berridge, Robinson, & Aldridge, 2009)) (Pecina, Cagniard, Berridge, Aldridge, & Zhuang, 2003). Given the reported similarities between drug addiction and overeating (for example; Gearhardt, Davis, et al., 2011; Meule, 2014), it has been proposed that enhanced wanting of foods, in particular highly palatable foods, may be a feature of so-called food addiction.

In an attempt to dissociate liking and wanting in human appetite, a unique behavioural paradigm was developed ten years ago. The Leeds Food Preference Questionnaire (LFPQ; Finlayson et al., 2008) measures subjective (explicit) liking for an array of pictorial food stimuli via visual analogue scales (VAS). The construct of (implicit) wanting is measured through a forced-choice task whereby food pictures are presented in pairs and choice reaction times provide an indication of non-verbal, implicit motivation (Finlayson et al., 2011; Tibboel, De Houwer, & Van Bockstaele, 2015). In a study of healthy adults, Finlayson et al. (2008) demonstrated that consumption of a savoury test meal caused explicit liking and wanting to decrease towards all food stimuli, yet with a more marked decrease towards savoury compared to sweet foods. However, implicit wanting was not suppressed with satiation, but rather increased towards sweet foods following meal consumption. These findings not only support a distinction between liking and wanting, particularly implicit wanting, but provide evidence for hedonically-driven, implicit wanting of sweet foods even in the satiated state immediately following meal consumption.

Though little is known about LFPQ responses in individuals varying in scores on the YFAS, differences in implicit wanting have been reported in trait binge eaters and obese samples. For example, Dalton, Blundell, and Finlayson (2013b) found that obese binge eaters displayed increased explicit liking and an enhanced implicit wanting for high fat sweet foods compared to obese non-binge eaters. Similarly, in non-obese females varying in scores on the Binge Eating Scale (BES; Gormally et al., 1982), Finlayson et al. (2011) found trait binge eating was associated with greater explicit liking and implicit wanting for high fat sweet food items. Such studies concluded that trait binge eating may represent a “hedonic subtype” of obesity (Dalton, Blundell, & Finlayson, 2013a; Dalton et al., 2013b; Davis et al., 2009). Given the similarities between FA and binge eating previously reported in this thesis (see Chapter 2 and Chapter 4), it could be assumed that individuals who identify as ‘food addicts’ according to the YFAS will display similar responses to the LFPQ as binge eaters. Specifically, increased implicit wanting towards high fat, sweet foods in individuals scoring highly on the YFAS will demonstrate heightened implicit wanting in these individuals. Whilst this could be implicated as support for FA, given that compulsive drug intake is well-reported to be driven by hedonic mechanisms (Ahmed & Koob, 1998; Koob & Le Moal, 1997; Volkow, Fowler, Wang, & Goldstein, 2002), it is also possible that the similarities in hedonic responsiveness in those with high scores on the BES and YFAS further emphasises the lack of dissociation between the constructs which these scales may be measuring. This concept is yet to be empirically tested and it is unknown whether higher scores on the YFAS will reveal any dissociation between liking and wanting akin to the anecdotal reports of those with substance use disorders.

7.2.2 Assessment of eating behaviour in relation to the YFAS

Whilst laboratory-based studies of eating behaviour amongst individuals varying in scores on the YFAS are lacking (C. G. Long et al., 2015; Ziauddeen et al., 2012b), a limited number of free-living assessments of EI in conjunction with the YFAS have been conducted using food recall methodology. For example, Pedram et al. (2013) measured macronutrient intake over the previous 12 months using the Willett Food Frequency Questionnaire (FFQ; Willett et al., 1985) in a large community sample. The amount of macronutrient consumed per kg of body weight did not differ between those who met the YFAS criteria for FA and those who did not. However, percentage calorie intake from protein and fat were higher in the FA compared to Non-FA subjects. The potential limitations of expressing nutrient intake per kilogram bodyweight must also be considered. Though this method allows comparison with The Reference Nutrient Intake (RNI; Department of Health, 1991), it has also been argued that intakes of individual nutrients should be references against the bodily functions which critically require these nutrients (Nutrition Reviews, 1952).

Conversely, Pedram and Sun (2014) followed the same methodology in a sample of 58 overweight/obese individuals. Of the macronutrients, these authors reported that those meeting the YFAS criteria for FA consumed more calories and carbohydrates per kg of body weight compared to those not meeting the YFAS criteria, as well as a greater consumption of fat and energy from fat. In addition, the FA group consumed significantly greater quantities of sugar and selenium, saturated, trans and monounsaturated fats compared to the Non-FA group. Evidently, there are inconsistencies regarding which nutrients so-called food addicts consume, though the evidence seems to implicate fat consumption with increasing YFAS score.

Moreover, Pursey et al. (2015) utilised the Australian Eating Survey food frequency questionnaire (AES FFQ; Collins et al., 2014), a 120-item FFQ used to assess typical dietary intake over the previous 6-months. In their sample of Australian young adults, no differences in total energy intake or percentage intake from protein carbohydrates or fat between the FA and Non-FA groups were found. However, percentage energy intake from fat was associated with a greater likelihood of receiving an FA classification, even when adjusted for age, sex and BMI. Furthermore, positive associations between YFAS ‘symptom count’ and percentage intake from confectionery, fat and energy-dense foods were revealed.

Taken together, these studies suggest that, regardless of obesity status, those individuals with high scores on the YFAS tend to consume more energy from fat, compared to those with lower scores. However, such research relies on self-report methodologies, which are prone to misreporting (Archer, Hand, & Blair, 2013; Blundell et al., 2009).

7.2.3 Cravings

Part of the reason why individuals who meet the YFAS criteria for FA seem to consume more fat compared to those who do not meet the YFAS criteria could be attributed to cravings. To date, research investigating the hedonic components of appetite control in relation to food addiction have been widely limited to measures of craving. Craving has been documented to play a key role in the development of both substance dependence and overeating (Dalton et al., 2015; T. E. Robinson & Berridge, 1993; Weingarten & Elston, 1991), whilst associations between ‘food addiction’, as defined by the YFAS, and cravings have been widely reported (Gearhardt, Rizk, & Treat, 2014; Meule & Kübler, 2012a; Polk et al., 2016). This has led to suggestions that craving may be enhanced in YFAS-defined ‘food addicts’, particularly towards those palatable foods high in ingredients such as fat and carbohydrates (Gearhardt, Rizk, et al., 2014; Joyner, Gearhardt, & White, 2015).

In an attempt to dissociate craving (i.e., wanting) and liking in FA, Polk et al. (2016) investigated perceptions of craving and liking in relation to pictorial food stimuli. The authors reported that highly “processed” foods (i.e., those higher in fat and carbohydrate) were craved more frequently and that this relationship was positively predicted by YFAS score. However, YFAS score did not affect ratings of liking of high fat/carbohydrate foods, suggesting a distinct role of YFAS scores in craving but not in liking. Although these results favour a distinction between wanting and liking in FA, subjective interpretation of wanting and liking are prone to bias. For example, self-report surveys such as those reported by Polk et al. (2016) can only lead to interpretation of the explicit processes which influence appetite, and it has been reported that individuals fail to distinguish between the affective and motivational aspects of wanting (Finlayson, King, & Blundell, 2007a). The present study, therefore, will employ the Control of Eating Questionnaire (CoEQ; Dalton et al., 2015) as a measure of craving across individuals varying in YFAS score, as well as the LFPQ to assess liking and (implicit) wanting using a validated behavioural paradigm.

7.2.4 Laboratory versus free-living assessment of eating behaviour

Though important in advancing understanding of human eating behaviours, assessing eating behaviour using free-living assessments applies minimal experimental control in order to obtain greater ecological relevance (Blundell et al., 2009). In particular, food recall designs are often limited by under-reporting, particularly with increasing body mass index (R. Hill & Davies, 2001; Moshfegh et al., 2008; Schoeller, 1995). In contrast, EB measurement in an acute laboratory setting allows researchers to be confident in the sensitivity of the experimental manipulation, isolating specific factors of interest and their impact on appetite control, free from extraneous factors. In addition, precision in measurement and reporting of EI can be enforced by the researchers by following strict methodological procedures. However, by enforcing such levels of experimental control, these laboratory experiments forgo some degree of the natural eating circumstances and behaviours of the subjects (Blundell et al., 2009; Stubbs et al., 2014). In these experimental procedures, there is a trade-off between the naturalness of the behaviours and the precision in measuring such behaviours (Blundell et al., 2009), therefore employing both methodologies would help to mitigate the limitations of each approach.

Collectively, therefore, the present chapter aims to address a gap in the literature regarding the food intake, preference and hedonic processes in individuals varying in scores on the YFAS. This will be achieved by utilising a 48-hour combined laboratory test-meal assessment (including the LFPQ) and free-living food recall design. Based on current knowledge, the work in this chapter is the first of its kind to measure combined laboratory and free-living EI, as well as objectively measured liking and wanting using a validated behavioural paradigm, in relation to the YFAS.

7.2.5 Objectives

The present chapter is a secondary analysis of a combined 24-hour laboratory test meal assessment and 24-hour free-living dietary recall investigation of eating behaviour (Dalton et al., 2013b). By utilising data on the food addiction symptomatology of the sample according to the YFAS, the aims of the present study are three-fold: 1) to investigate any differences in energy and macronutrient intake, particularly fat, in laboratory and natural settings across tertiles of YFAS scores; 2) to explore any differences in explicit liking, explicit wanting and implicit wanting towards high and low fat, sweet and savoury foods according to the LFPQ, before and after an *ad libitum* lunch test-meal; and 3) to explore the degree of craving across tertiles of YFAS scores.

Specifically, it can be hypothesised that: (H_1) the highest tertile of YFAS scores will consume more energy and/or fat compared to low tertiles; (H_2) individuals in the highest tertile of YFAS scores will display increased explicit and implicit wanting for, and bias towards, high fat foods according to the LFPQ; and (H_3) the highest tertile of YFAS scores will present the greatest levels of craving according to the CoEQ.

7.3 Methods

7.3.1 Participants

34 female adult (age: 25.24 ± 5.69, BMI: 27.45 ± 5.46) participants were recruited from the staff and student population from the University of Leeds. Eligibility was determined through a screening questionnaire. Participants were excluded if they were: current or recent smokers, taking medication known to affect appetite, current dieters, reported a history of eating disorders, had known allergies or intolerances to study foods or disliked the study foods. Participants provided written informed consent, were fully debriefed upon completion of the full study protocol and were remunerated £15 upon completion of the study. All research procedures were reviewed and approved by the School of Psychology Ethical Review Committee.

At the end of the study protocol, the YFAS was administered to participants. Participants' scores on the YFAS were used retrospectively to group subjects for the present analyses into a low FA (LFA), moderate FA (MFA) or high FA (HFA) group based on a tertile split of YFAS 'symptom count' scores. The LFA group contained 15 subjects and all subjects had a YFAS 'symptom count' of 1.

The MFA group included 9 subjects all of whom had a YFAS ‘symptom count’ of 2. The HFA group contained 10 subjects who had a YFAS ‘symptom count’ of ≥3 (mean: 5 ± 1.83).

7.3.2 Study design

The study consisted of 2 experimental sessions across 3 days. The experimental sessions were conducted on weekdays to avoid weekend fluctuations in energy intake. Both sessions were conducted in the follicular phase (days 1-14) of participants’ menstrual cycle in order to prevent any influence of the luteal phase on EI and food preference (I. T. Cohen, Sherwin, & Fleming, 1987; Dye & Blundell, 1997).

The first experimental session involved a 24-hour test meal (henceforth referred to as TM) methodology in the laboratory. For this visit, participants arrived at the laboratory between 07:00 and 09:00. Participants were required to arrive in a fasted state, having not eaten or drunk anything (except water) from 9pm the previous night. Upon arrival at the TM session, anthropometric measurements (height, weight, waist circumference, body composition) were taken. Following this, breakfast, lunch, afternoon snacks and dinner were served to participants, with each meal separated by a four-hour period. Immediately before and 10-minutes after the *ad libitum* lunch meal, the LFPQ was completed by participants. For all meals, participants were placed in individual feeding cubicles free from distractions. Participants were free to leave the research unit in between meals but were instructed not to consume anything except for the food and drinks provided by the researchers during this time. Ratings of subjective appetitive, gastrointestinal and mood sensations were taken at regular intervals throughout the probe days: every hour throughout the day with the first rating immediately before breakfast, immediately after each meal and immediately before and after the LFPQ.

The second experimental session took place two days after the TM session. This involved a dietary recall (henceforth referred to as DR) assessment of free-living energy intake from the previous 24-hours using the validated Automated Multiple Pass Method (AMPM; Moshfegh et al., 2008). Subjects were required to recall all foods and beverages consumed from the time they left the laboratory after the TM session until 10pm on the evening before the

DR session. The purpose of the DR session was not disclosed to participants prior to the session in order to prevent participants from intentionally modifying, restricting or rehearsing their food intake for the purpose of the study.

7.3.3 Measures

7.3.3.1 Eligibility testing

Participants expressing an interest in the study procedure were sent a direct link to an online screening questionnaire (distributed using SurveyMonkey Inc.; San Mateo, California, USA, www.surveymonkey.com) to determine eligibility. This included a short demographic questionnaire (measuring general health, diet status, lifestyle and physical activity levels) and a measurement of binge eating.

7.3.3.1.1 Binge Eating Scale (BES; Gormally et al., 1982)

The BES was utilised in order to measure trait binge eating. This scale is described in detail in Chapter 4.

7.3.3.2 Preliminary assessment

At first attendance at the research unit, participants' anthropometric measurements were taken in the fasted state.

7.3.3.2.1 Body composition

Whole body air-displacement plethysmography using the BodPod (Life Measurement Instruments, Concord, CA) was used to determine subjects' fat mass (FM), fat free mass (FFM) and percentage body fat (%BF). This measure is described in greater detail in Chapter 6. Body weight (kg), height (cm) and waist circumference (cm) were also measured. Subjects' measured height and weight was used to determine body mass index (BMI; kg/m2).

7.3.3.2.2 Estimation of total daily energy expenditure

Estimated daily energy expenditure was calculated using the Schofield equation for basal metabolic rate (Schofield, 1984), multiplied by physical activity level (PAL). PAL was determined using the self-reported mode and frequency of physical activity performed per week, as reported in the screening questionnaire.

7.3.3.3 Test-meal methodology

7.3.3.3.1 Visual analogue scales

At fourteen predetermined time points throughout each testing session (immediately before and immediately after consuming each meal, immediately before and immediately after measures of food hedonics, and every 60 minutes until the end of the experimental day), subjects were required to complete Visual Analogue Scales (VAS) using the hand-held Electronic Appetite Rating System (EARS-II; Gibbons et al., 2011). This method is described in detail in Chapter 6. The time points at which the ratings were obtained is depicted in Appendix G.

7.3.3.3.2 Food hedonics

The Leeds Food Preference Questionnaire (LFPQ; Finlayson et al., 2007b; Finlayson et al., 2008) was used to measure explicit liking and implicit wanting towards an array of pictorial food stimuli, representing common food items. The LFPQ has been validated in a wide-range of research (for example, Finlayson et al., 2011; Griffioen-Roose, Finlayson, Mars, Blundell, & de Graaf, 2010). The food stimuli are categorised according to individual fat content: high fat (HF; >50% energy) or low fat (LF; <20% energy) and taste: sweet (SW) or savoury (SA), or combined categories of high fat sweet (HFSW), low fat sweet (LFSW), high fat savoury (HFSA) or low fat savoury (LFSA). Examples of the food images included in the LFPQ are depicted in *Figure 25* and their nutritional information is included in *Table 24*.

Figure 25. Food images included in the LFPQ

Table 24. Nutritional information for LFPQ food images

Food Category	Food	% Protein	% Carb	% Fat	KCAL per 100g
HFSW	Jammy dodgers	4.60	65.60	28.80	432
	Milk chocolate	6.30	37.10	53.20	538
	Chocolate Fingers	5.80	42.50	47.90	520
	Glazed doughnut	5	40.60	50.40	405
HFSA	Fries	4.70	53.40	38.50	255
	Crisps	4.60	36.40	54.60	526
	Salted peanuts	17.30	8.60	71.40	609
	Garlic bread	6.90	39.50	50.20	454
LFSW	Skittles	0	84.30	9.40	404
	Straw-berries	7.30	69.30	13.60	33
	Red apple	4.30	95.70	9.60	47
	Marsh-mallows	.20	92.70	.90	329
LFSA	New potatoes	8.40	90.80	.80	75
	Bread roll	12.90	68.70	11.50	251
	Red peppers	13.50	86.30	9	20
	Cucumber	5.50	47.70	40.90	11

To measure explicit liking, food images were presented individually, in a randomised order and participants were required to rate: “How pleasant would it be to taste some of this food now?” on 100-mm VAS with anchor points on each end ranging from ‘not at all’ to ‘extremely’. Ratings for each food item are averaged for each food category. Explicit wanting was assessed in the same way but to the question: “How much do you want some of this food now?”. An example of the explicit liking and explicit wanting trials in the LFPQ are represented in *Figure 26*.

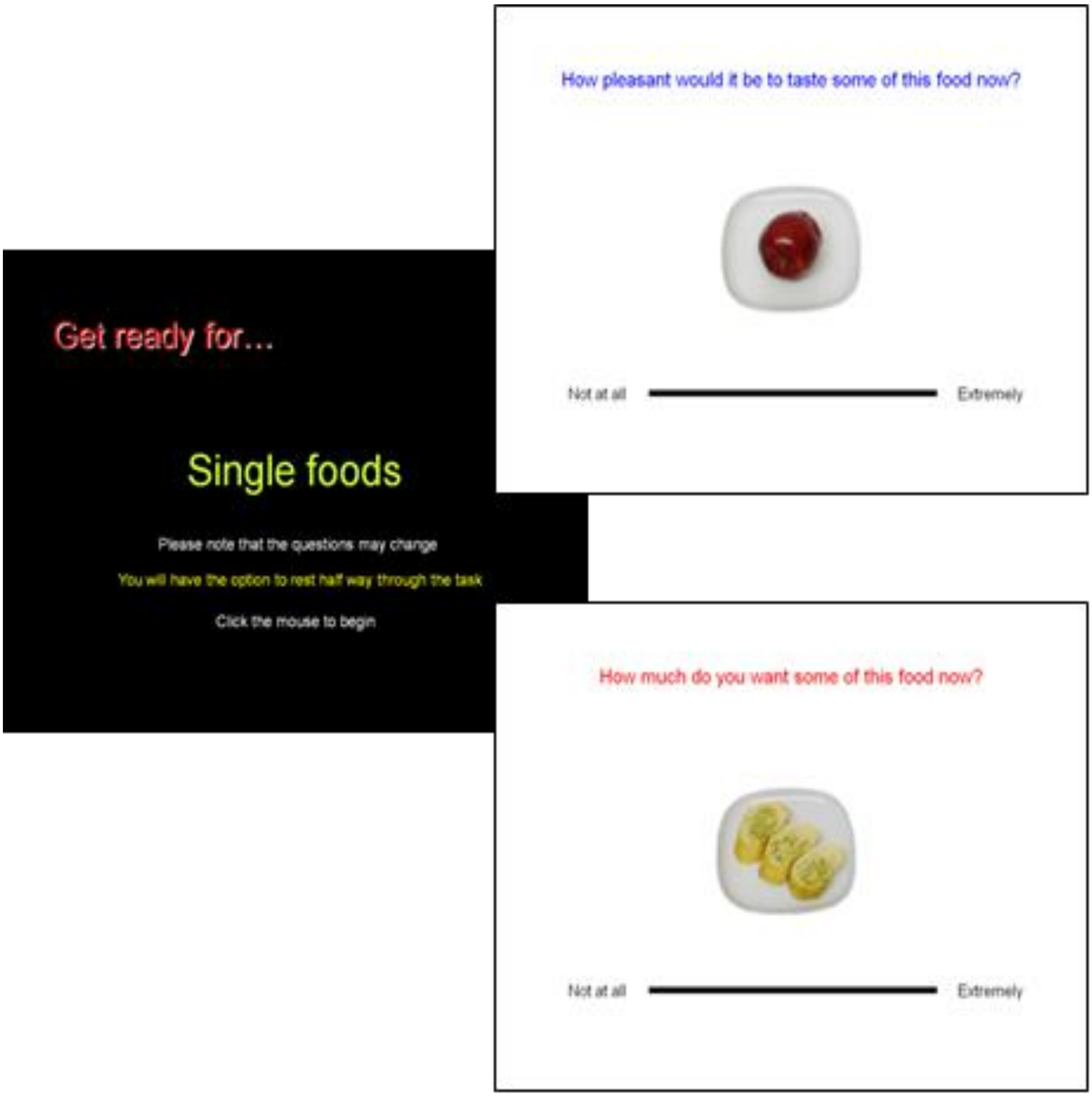


Figure 26. Representation of the explicit liking (top) and explicit wanting (bottom) trials in the LFPQ

To measure implicit wanting, participants were presented with food pairs and asked to respond as quickly and accurately as possible in a forced-choice methodology in response to the question: “Which food do you most want to eat now?”. Each food stimulus in each of the four combined food categories is paired with each item in the other categories over 96 trials. Reaction times for all responses were recorded and used to compute mean response times for each food category after adjusting for frequency of selection. A faster response time in one category relative to the other categories, indicates a greater ‘implicit wanting’ of foods in this category, therefore a positive score represents a more rapid preference for the given food category relative to the alternative categories. An example of an implicit wanting trial is represented in *Figure 27*.

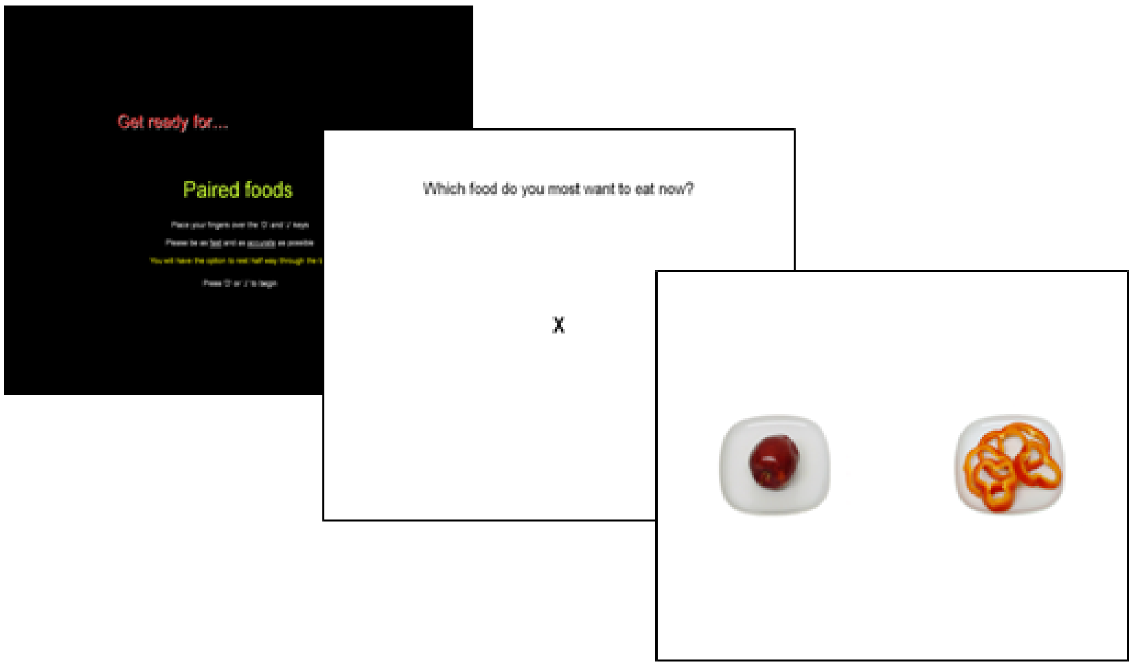


Figure 27. Representation of the implicit wanting trials in the LFPQ

7.3.3.4 Energy intake measures

All meals were prepared by the researchers in the research unit following the appropriate standard operating procedures. All foods were weighed before and after consumption to the nearest 0.10g to calculate energy intake (EI) and ensure compliance. All meals were served to participants in individual testing cubicles.

7.3.3.4.1 *Ad libitum* breakfast

Participants selected either Cornflakes or Branflakes and either white or wholemeal bread for consumption at breakfast, with accompaniments, served *ad libitum*. Tea or coffee (1 mug) were provided on request with the optional addition of sugar, and water was provided *ad libitum*. Participants were instructed to take as much time as they liked to consume as much or as little of any of the foods until they were comfortably full. Details of the breakfast foods, their nutritional compositions and the quantity provided are included in *Table 25.*

Table 25. Food items, nutritional composition and quantities of the *ad libitum* breakfast

Food Item	Kcal/100g	Protein /100g	CHO/100g	Fat/100g	Quantity provided
Kellogg's Cornflakes	372	7	84	.90	175g
Kellogg's Branflakes	356	10	67	2	175g
Semi-skimmed milk	49	3.40	5	1.70	500ml
Wholemeal bread	216	11.10	36.10	3	4 slices
White bread	226	8	44.10	2	4 slices
Flora spread	531	<.50	<.50	45	30g
Strawberry jam	254	.50	61.90	.10	30g
Granulated sugar	400	<.50	100	<.50	50g

7.3.3.4.2 *Ad libitum* lunch

3-hours after the breakfast meal was served, an *ad libitum* lunch meal was served to participants. The lunch meal consisted of two types of sandwiches, each cut into quarters. Participants were instructed to finish eating the entire quarter if they began to eat it, to assist with calculations of EI. Bread preference (white or wholemeal) was the same as in the breakfast test meal. Participants were instructed to take as much time as they liked to consume as much or as little of any of the foods until they were comfortably full. Details of the lunch foods, their nutritional compositions and the quantity provided are included in *Table 26*.

Table 26. Food items, nutritional composition and quantities of the *ad libitum* lunch

	Food Item	Kcal /100g	Protein /100g	CHO /100g	Fat/100g	Quantity provided
Wholemeal bread		216	11.10	36.10	3	2 slices
White bread		226	8	44.10	2	2 slices
Cheese sandwich	Grated cheddar cheese	410	24.80	.90	34.10	45g
	Flora spread	531	<.50	<.50	45	10g
Cream cheese sandwich	Low-fat cream cheese	152	7.40	5.10	11	34g
	Flora spread	531	<.50	<.50	45	10g
Onken Strawberry Yoghurt		111	4.10	17.20	2.90	300g
Cheese savouries		527	11	50	31	100g

7.3.3.4.3 *Ad libitum* afternoon snacks

After completion of the lunch session, participants were provided with a snack box to consume away from the lab during the afternoon until the dinner session. The snacks included four pre-selected foods chosen to represent each of the food categories in the LFPQ (high fat savoury; HFSA, high fat sweet; HFSW, low fat savoury; LFSA, high fat savoury; HFSA). These foods were selected by the participants during the screening session. Subjects were asked to rank each of the snack foods from “most preferred” to “least preferred”, then rate each snack food on its pleasantness and frequency of consumption using 7-point Likert scales. The most preferred item from each group was then provided to participants. 100g of each food was presented in clear plastic food bags, and provided in a jute bag for participants to take-away and consume, if they wished. Participants were instructed to consume as much or as little of any of the foods as they liked, but not to share, give away or dispose of any of the items. Participants were instructed to return all elements of the snack box, including empty packaging and partially-eaten foods, to the research unit at the beginning of the dinner session. Details of the potential snack foods, their nutritional compositions and the quantity provided are included in *Table 27*.

Table 27. Food items, nutritional composition and quantities of the *ad libitum* afternoon snacks

Food category	Food Item	Kcal/100g	Protein /100g	CHO/100g	Fat/100g
HFSA	Mini Cheddars	516	11.20	50.70	29.80
	Walkers Ready Salted crisps	537	5.90	49.70	34.10
	Jacobs TUC crackers	513	7.30	56.50	28.60
HFSW	Cadbury's chocolate buttons	525	7.50	56.80	30
	Maryland mini choc cookies	502	5.80	62.50	25.50
	Bakin' Boys Flapjack	464	4.50	60.20	24.30
LFSA	Snack-a-Jacks	415	8	79	7.50
	Salted pretzels	285	10.30	76.70	4.20
	Ryvita Thins multi-seed	358	12.90	54.10	10
LFSW	Bassett's Jelly Babies	335	3.60	79.80	<.10
	Maynard Wine Gums	325	6.10	75	.20
	Rowntree's Fruit Pastilles	351	4.40	83.60	.10

Note: HFSA = high fat savoury; HFSW = high fat sweet; LFSA = low fat savoury; LFSW = low fat sweet

7.3.3.4.4 *Ad libitum* dinner

3-hours after the lunch meal was served, dinner was served to participants. Dinner consisted of pasta and tomato sauce with cheese, garlic bread, a side-salad and chocolate rolls for desert. Participants were provided with a plate to serve themselves and were able to request more of any of the elements, if they wished. All foods were served *ad libitum* and participants were instructed to take as much time as they liked to consume as much or as little of any of the foods until they were comfortably full. Details of the dinner foods, their nutritional compositions and the quantity provided are included in *Table 28*.

Table 28. Food items, nutritional composition and quantities of the *ad libitum* dinner

Food Item	Kcal/100g	Protein/100g	CHO/100g	Fat/100g	Quantity provided
Pasta	346	12	70	2	300g
Tomato and herb sauce	54	2	8.80	1.20	475g
Grated cheddar cheese	410	24.80	.90	34.10	100g
Plain baguette	242	7.80	49.70	1.30	85g
Garlic baguette	368	7.30	45.60	17.40	85g
Iceberg lettuce	13	.70	1.90	.30	150g
Tomatoes	18	.70	3.10	.30	115g
Cucumber	10	.70	1.50	.10	115g
Chocolate Swiss rolls	406	4.10	55.40	18.30	80g

7.3.3.5 24-hour free-living dietary recall methodology

Following one wash-out day after the laboratory-based TM session, participants returned to the research unit. Here, participants' free-living energy intake was assessed using the United States Department of Agriculture's Automated Multiple Pass Method (AMPM: Moshfegh et al., 2008) of dietary recall. Participants were asked to recall all food and beverage consumption from the time they left the research unit on day 1 (after the TM session) until 10pm the following day.

The AMPM uses a structured interview following 5 steps. Firstly, subjects provided a 'quick list' of all food and beverages consumed in the appropriate time period, without interruption from the researcher. Subjects were asked to recall the day's events in order to assist with dietary recollection. Next, the researcher presented a 'forgotten foods' list, comprising of nine categories of food which are often forgotten: non-alcoholic beverages, alcoholic beverages, sweets, savoury snacks, fruit, vegetables, cheeses, breads and rolls, and any other foods. Subsequently, participants were probed about when they ate each food item previously listed and to name the eating occasion (e.g., breakfast, lunch, dinner, snack). This stage aimed to assist in recalling any forgotten foods during these eating episodes. Following this, subjects were asked to provide detailed information about each food recorded, such as brand, any additions to the food item (e.g., sauces), amount eaten, its source (supermarket versus restaurant) and whether the item was consumed at home. Each eating occasion was reviewed and any intervals between eating episodes revisited to prompt further recall. Finally, a final probe provided subjects with a final opportunity to recall foods they may have forgotten, or any small quantities of foods they may not have thought worth mentioning. Enquiries about whether the amount eaten was typical or more or less than usual were conducted. Measuring cups and spoons, rulers and images of typical food portions were provided to assist in participants' estimations of portion size.

Following completion of the AMPM, participants were instructed to complete the final psychometric questionnaires, as described below, then were fully debriefed on the study procedures and remunerated for their time before leaving.

7.3.3.6 Psychometric questionnaires

At the end of the DR session, participants completed three psychometric measures of eating behaviour. These included the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985), Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009b) and Control of Eating Questionnaire (CoEQ; Dalton et al., 2015), all of which are described in detail in Chapter 4.

7.3.4 Procedure

A flowchart depicting the full study timeline is displayed in *Figure 28*. A flowchart depicting the procedure of the TM session is depicted in *Figure 29*.

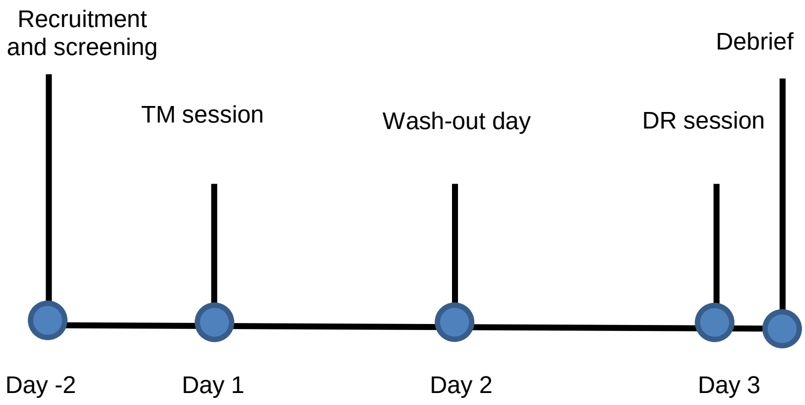


Figure 28. Flowchart depicting the full study timeline

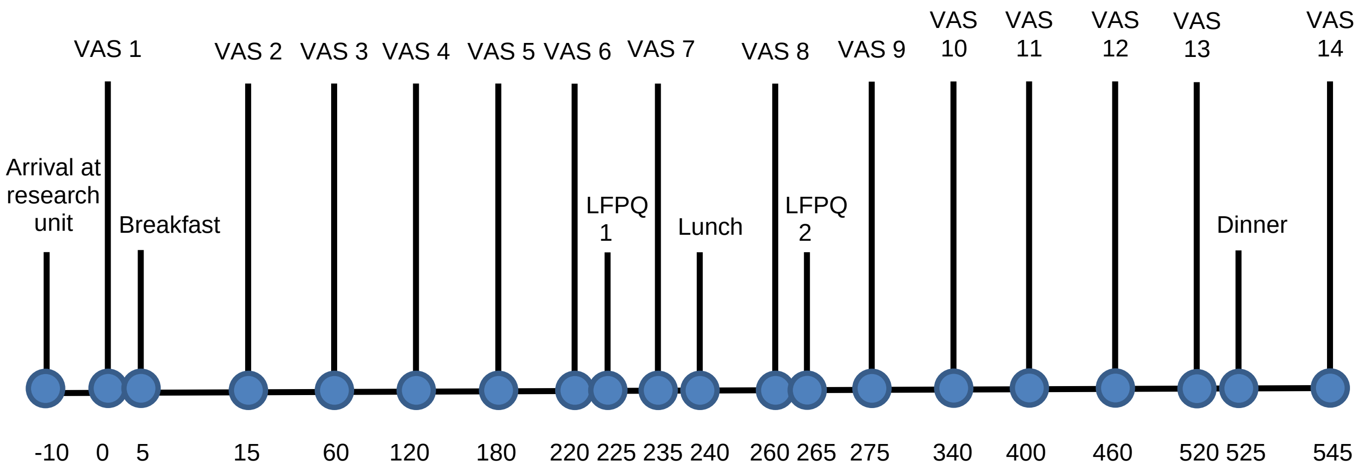


Figure 29. Figure depicting the TM session procedure

7.3.5 Data analysis plan

All data analysis was carried out using SPSS Statistics (IBM Corp., Armonk, NY) version 23. Results are reported as Mean (±SD) unless otherwise specified.

Differences in participant characteristics, including anthropometrics and psychometric scales, across the three YFAS groups were compared using one-way ANOVAs and significant effects were further explored using independent samples *t*-tests. Using the visual analogue scales, the effect of YFAS group on 24-h ratings of hunger, fullness, desire to eat and prospective consumption were assessed using a 14 (time point; TP) x 3 (LFA, MFA, HFA) mixed model ANOVA with YFAS group as the between-subjects variable.

Differences in energy intake in each of the eating episodes in the TM and DR sessions were compared across YFAS groups using one-way ANOVAs and significant effects were further explored using independent samples *t*-tests. Where significant differences in YFAS groups were evident, graphs are displayed to depict the data. Differences in energy intake from the different food categories included in the TM snack box across YFAS groups were analysed using a 4 (food category: HFSA, HFSW, LFSA, LFSW) x 3 (LFA, MFA, HFA) mixed model ANOVA with YFAS group as the between-subjects factor.

In order to assess the validity of the dietary recall assessment, Pearson's correlations were used to examine the relationship between laboratory-based and free-living measures of energy intake. Values of Pearson's correlation coefficient (*r*) for small, medium and large effects, respectively, are .1, .3, and .5 (J. Cohen, 1988, 1992).

Food hedonics were analysed using a 2 (motivational state: pre- or post-lunch) x 4 (food category: HFSA, LFSA, HFSW, LFSW) x 3 (LFA, MFA, HFA) mixed model ANOVA using YFAS group as the between subjects factor for each of the components of food hedonics (explicit liking, explicit wanting, implicit wanting).

Where Maulchly's Test of Sphericity was significant (p <.05), the Greenhouse Geisser correction was applied to overcome the violation of sphericity. The Bonferroni correction for multiple comparisons was applied when post-hoc analyses revealed a significant effect. Effect sizes were calculated using partial eta squared (η_p^2) or Cohen's *d*, whereby the values for small, medium and large effects, respectively, for η_p^2 are .0099, .0588, and .1379 (Richardson, 2011), and for Cohen's *d* are .2, .5, and .8 (J. Cohen, 1988, 1992).

One-way ANOVAs were employed to investigate differences in meal and snack consumption between YFAS tertiles using the AMPM dietary recall data and significant effects were further explored using independent samples *t*-tests. 24-h macronutrient consumption during the dietary recall day was explored across YFAS tertiles using one-way ANOVAs and independent samples *t*-tests were conducted where significant results existed. For all ANOVA analyses alpha was set at p <.05.

7.4 Results

7.4.1 Sample characteristics

The mean participant characteristics for each of the YFAS groups are displayed in *Table 29*. One-way ANOVAs revealed no significant differences between YFAS groups in any of the demographic variables outlined in *Table 29*, as indicated by column '*p*'.

Table 29. Participant characteristics for the LFA, MFA and HFA groups

	LFA (N=15)	MFA (N=9)	HFA (N=10)	*p*
Age	24.93 (±5.40)	26.22 (±5.36)	24.80 (±6.83)	.84
Body mass (kg)	73.08 (±12.95)	73.53 (±11.83)	84.18 (±22.72)	.22
BMI (kg/m^2)	26.44 (±4.51)	27.03 (±4.29)	29.35 (±7.44)	.43
Fat mass (kg)	24.11 (±7.90)	22.52 (±7.35)	34.02 (±17.72)	.07
Fat-free mass (kg)	48.27 (±7.24)	49.78 (±4.98)	50.15 (±6.35)	.74
Body fat (%)	32.61 (±7.24)	30.01 (±6.17)	37.86 (±11.11)	.12
Waist (cm)	84.61 (±10.55)	84.73 (±12.10)	93.31 (±19.91)	.29
Estimated RMR	1551.82 (±199.50)	1554.06 (±178.32)	1653.98 (±269.07)	.47

Note: Results are Mean (±SD). BMI: body mass index; RMR: resting metabolic rate.

7.4.2 Eating behaviour traits

One way ANOVAs were conducted to compare eating behaviour traits across YFAS groups (*Table 30*). By design, the three groups differed in YFAS 'symptom count' ($F(2, 31) = 50.83$, p <.001). Four participants met the dichotomous YFAS criteria for FA. All four of these participants were included in the HFA group.

There were significant differences between groups on scores on the Binge Eating Scale ($F(2, 31) = 7.73$, $p < .01$), TFEQ restraint ($F(2, 31) = 7.16$, $p < .01$), disinhibition ($F(2, 31) = 8.32$, $p < .01$) and hunger ($F(2, 31) = 3.83$, $p < .05$) subscales, and CoEQ craving for sweet subscale ($F(2, 31) = 5.45$, $p < .05$; *Table 30*).

Independent samples *t*-tests revealed the HFA and MFA groups had significantly higher scores on the BES compared to LFA ($t(23) = 3.82$, $p < .01$, $d = 1.62$ and $t(22) = 2.20$, $p < .05$, $d = .97$, respectively). The HFA group had significantly higher restraint compared to LFA ($t(23) = 4.39$, $p < .001$, $d = 1.87$), and greater disinhibition compared to MFA ($t(17) = 3.12$, $p < .01$, $d = 1.52$) and LFA ($t(23) = 3.87$, $p < .01$, $d = 1.65$) according to the TFEQ. The LFA group had significantly lower TFEQ hunger compared to MFA ($t(22) = 2.17$, $p < .05$, $d = .96$) and HFA ($t(23) = 2.52$, $p < .05$, $d = 1.07$), whilst the HFA group had significantly greater cravings for sweet foods compared to MFA ($t(16) = 2.19$, $p < .05$, $d = 1.10$) and LFA ($t(21) = 2.98$, $p < .01$, $d = 1.33$).

Table 30. Eating behaviour traits in the LFA, MFA and HFA groups

	LFA (N=15)	MFA (N=9)	HFA (N=10)	*p*
YFAS 'symptom count'	1 (±0)	2 (±0)	5 (±1.83	.001***
BES	7.13 (±5.85)	12.78 (±6.44)	18.20 (±8.70)	.00**
TFEQ Restraint	7.60 (±3.52)	9.56 (±5.15)	13.60 (±3.06)	.00**
TFEQ Disinhibition	7.60 (±3.31)	8.33 (±3.00)	12.70 (±3.09)	.00**
TFEQ Hunger	5.13 (±3.20)	8.22 (±6.67)	8.60 (±3.63)	.03*
CoEQ Craving Control	51.17 (±12.66)[1]	51.87 (±14.26)	43.29 (±25.45)	.50
CoEQ Craving Sweet	44.44 (±14.88)[1]	49.25 (±11.47)	66.47 (±20.59)[2]	.01*
CoEQ Craving Savoury	41.00 (±15.77)[1]	50.50 (±13.09)	48.69 (±26.10)[2]	.43
CoEQ Positive Mood	64.61 (±16.37)[1]	62.42 (±12.54)	48.58 (±19.70)[2]	.08

Note: Results are Mean (±SD). YFAS: Yale Food Addiction Scale; BES: Binge Eating Scale; TFEQ: Three-Factor Eating Questionnaire; CoEQ: Control of Eating Questionnaire. [1] N=14, [2] N=9.
* = *p*<.05, ** = *p*<.01, *** = *p*<.001.

7.4.3 Appetite ratings

Repeated measures ANOVAs were conducted to compare ratings of hunger, fullness, desire to eat and prospective consumption across the meal days in each YFAS group.

7.4.3.1 Hunger

There were no significant differences in baseline hunger (TP 1) across the YFAS groups (*p* =.53). Throughout the day a significant main effect of time on hunger ratings was found (F(4.98, 154.51) = 100.29, *p* <.001, η_p^2 =.76). However, there was no main effect of YFAS group (*p* =.40), nor an interaction between YFAS group and time on hunger ratings (*p* =.72). These results are depicted in Appendix H.

7.4.3.2 Fullness

There were no significant differences in baseline fullness (TP 1) across the YFAS groups (*p* =.66). Throughout the day a significant main effect of time on fullness ratings was found ($F(5.14, 159.43) = 80.79$, $p < .001$, $\eta_p^2 = .72$). However, there was no main effect of YFAS group (*p* =.33), nor an interaction between YFAS group and time on fullness ratings (*p* =.70). These results are depicted in Appendix I.

7.4.3.3 Desire to Eat

There were no significant differences in baseline desire to eat (TP 1) across the YFAS groups (*p* =.50). Throughout the day a significant main effect of time on desire to eat ratings was found $F(5.51, 170.83) = 74.03$, $p < .001$, $\eta_p^2 = .71$). However, there was no main effect of YFAS group (*p* =.54), nor an interaction between YFAS group and time on desire to eat ratings (*p* =.85). These results are depicted in Appendix J.

7.4.3.4 Prospective consumption

There were no significant differences in baseline prospective consumption (TP 1) across the YFAS groups (*p* =.48). Throughout the day a significant main effect of time on desire to eat ratings was found $F(5.74, 177.96) = 82.36$, $p < .001$, $\eta_p^2 = .73$). However, there was no main effect of YFAS group (*p* =.35), nor an interaction between YFAS group and time on prospective consumption ratings (*p* =.77). These results are depicted in Appendix K.

7.4.4 Test meal consumption

7.4.4.1 Breakfast

A one-way ANOVA revealed no significant differences in energy intake (kcal) at breakfast between YFAS groups. These results are depicted in *Figure 30*.

7.4.4.2 Lunch

A one-way ANOVA revealed significant differences between YFAS groups in EI at lunch ($F(2, 31) = 5.51$, $p < .01$). Independent samples *t*-tests revealed that the MFA group (M: 920.80) consumed significantly more energy at lunch compared to LFA (M: 731.14; $t(22) = 3.34$, $p < .01$, $d = 1.47$) and HFA (M: 723.34; $t(17) = .2.49$, $p < .05$, $d = 1.21$). These results are depicted in *Figure 30*.

7.4.4.3 Snacks

A one-way ANOVA revealed significant differences between YFAS groups in EI from the snack foods ($F(2, 31) = 5.48$, $p < .01$). Independent samples *t*-tests revealed that the HFA (M: 762.47) and MFA (M: 607.61) groups ate significantly more calories from the snack foods compared to LFA (M: 406.42; $t(23) = 3.03$, $p < .01$, $d = 1.29$, and $t(22) = 2.63$, $p < .05$, $d = 1.16$, respectively). These results are depicted in *Figure 30*.

Whether energy intake (Kcal) from snacks as a percentage of TDEI differed across YFAS groups, a one-way ANOVA was conducted. The results revealed no significant difference in percentage of TDEI from snacks across YFAS groups ($p = .09$).

7.4.4.4 Dinner

A one-way ANOVA revealed significant differences between YFAS groups in EI at dinner ($F(2, 31) = 6.82$, $p < .01$). Independent samples *t*-tests revealed that the HFA group (M: 1025.98) consumed significantly more energy at dinner compared to the MFA (M: 721.90; $t(17) = 2.66$, $p < .05$, $d = 1.29$) and LFA (M: 715.63; $t(23) = 3.88$, $p < .01$, $d = 1.65$) groups. These results are depicted in *Figure 30*.

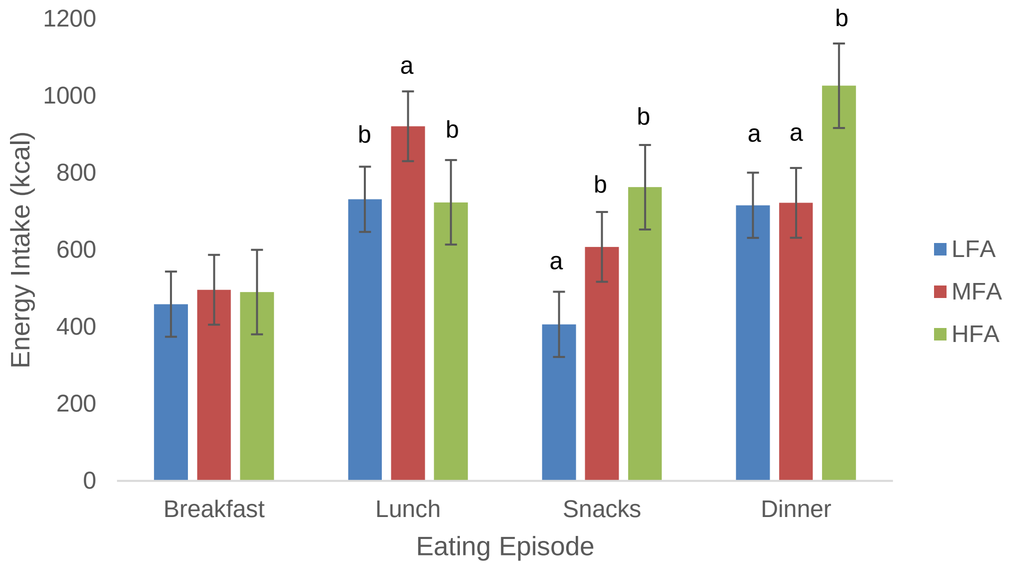


Figure 30. Energy intake (kcal) at breakfast, lunch, snacks and dinner in the LFA, MFA and HFA groups. Note: lines denote Standard Error. Unalike letters indicate significant difference (per eating episode).

7.4.4.5 Snack box food preference

Differences in energy intake (kcal) from the different food categories included in the snack box (HFSA, HFSW, LFSA, LFSW) across YFAS groups were analysed. There was a significant main effect of food category on EI (F(3, 93) = 21.34, *p* <.001, η_p^2 =.41). Post-hoc analyses revealed that subjects consumed significantly more energy from HFSW (M: 266.11) compared to LFSW (M: 142.44, *p* <.001), HFSA (M: 115.16, *p* <.001) and LFSA (M: 68.46, *p* <.001), and from LFSW compared to LFSA (*p* <.01).

There was also a significant main effect of YFAS group on EI (F(2, 31) = 5.48, *p* <.01, η_p^2 =.26), whereby post-hoc analyses revealed that the HFA group (M: 190.62) consumed significantly more energy from snacks compared to the LFA group (M: 101.61, *p* <.01).

There was also a significant interaction between food category and YFAS group (F(2, 31) = 7.05, *p* <.01, η_p^2 =.31). Post-hoc analyses revealed that the HFA group consumed significantly more energy from HFSW (M: 413.71) compared to MFA (M: 176.06, *p* <.01) and LFA (M: 208.56, *p* <.01), whereas the MFA group consumed significantly more energy from LFSW (M: 187.36) compared to LFA (M: 84.32, *p* <.05). Within groups, post-hoc analyses revealed that the HFA and LFA groups consumed the most energy from HFSW compared to the other food categories (all *p* <.001 in HFA and *p* <.05 in LFA), whilst MFA consumed the most energy from LFSW, though this did not significantly differ from the other food groups (all *p* >.28). These results are depicted in *Figure 31*.

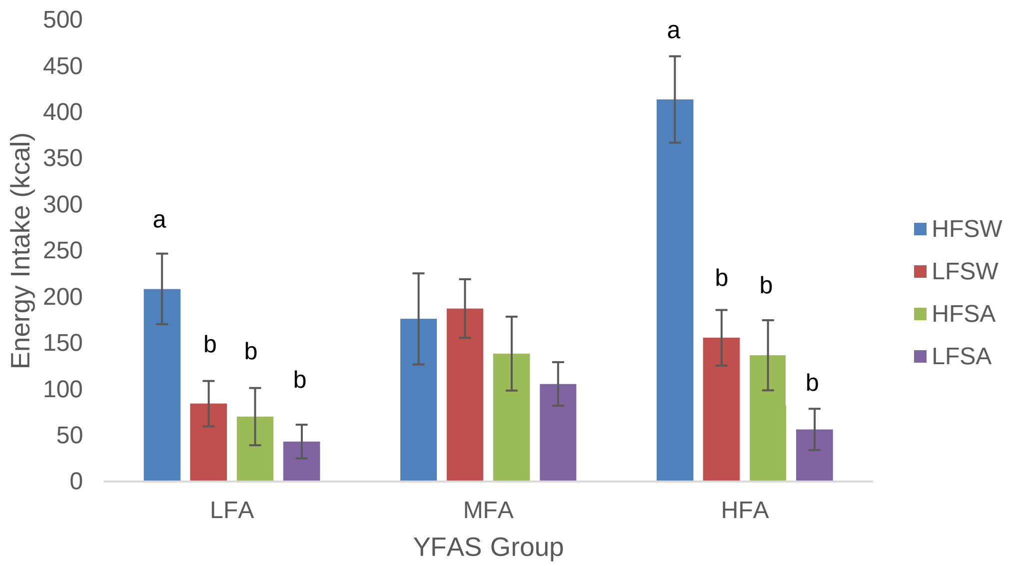


Figure 31. Energy intake (kcal) according to food category in the LFA, MFA and HFA groups. Note: lines denote Standard Error. Unalike letters indicate significant difference (per group).

7.4.5 Dietary recall consumption

7.4.5.1 Relationship between laboratory-based and free-living measures of energy intake

In order to assess the validity of the dietary recall assessment, Pearson's correlations were used to examine the relationship between laboratory-based and free-living measures of energy intake across all eating episodes, in the full sample. As shown in *Table 31*, overall EI and EI from snacks from TM and DR were positively correlated but there was no relationship between TM and DR breakfast, lunch or dinner intake.

Table 31. Pearson's correlations between energy intake (kcal) from the laboratory test meal session and dietary recall session.

		Laboratory Test Meal				
		Overall	Breakfast	Lunch	Dinner	Snacks
Dietary Recall	Overall	.59***				
	Breakfast		.05			
	Lunch			.08		
	Dinner				.19	
	Snacks					.43*

* = *p*<.05, ** = *p*<.01, *** = *p*<.001.

7.4.5.2 TM session evening recall

During the DR session, participants were required to recall any foods or beverages consumed during the evening after leaving the laboratory following the TM dinner. 24 subjects reported consumption during this this time (N=10 in LFA, N=7 in MFA and N=7 in HFA). One-way ANOVA revealed no significant differences across YFAS groups in EI during the evening following the TM session (p =.23).

7.4.5.3 Dietary recall meal consumption

One-way ANOVAs revealed no significant differences in EI during the DR day across YFAS groups at breakfast (p = .66), lunch (p = .23) or dinner (p = .54).

7.4.5.4 Dietary recall snack consumption

A one-way ANOVA revealed a significant difference in EI from snacks across the DR day between YFAS groups ($F(2, 31) = 5.58$, p <.01). Independent samples *t*-tests revealed that the HFA group (M: 731.52) consumed significantly more energy from snacks compared to the MFA (M: 224.43, p <.01) and LFA groups (M: 414.12, p <.05). These results are depicted in *Figure 32*.

Whether energy intake (Kcal) from snacks as a percentage of TDEI differed across YFAS groups, a one-way ANOVA was conducted. The results revealed a significant difference in percentage of TDEI consumed from snacks across YFAS groups in the DR session ($F(2, 33) = 4.26$, $p < .05$). Independent samples *t*-tests revealed that the HFA group consumed a greater proportion of calories from snacks as a percentage of TDEI (M: 26.01%) compared to the MFA group (M: 10.28%, $p < .05$).

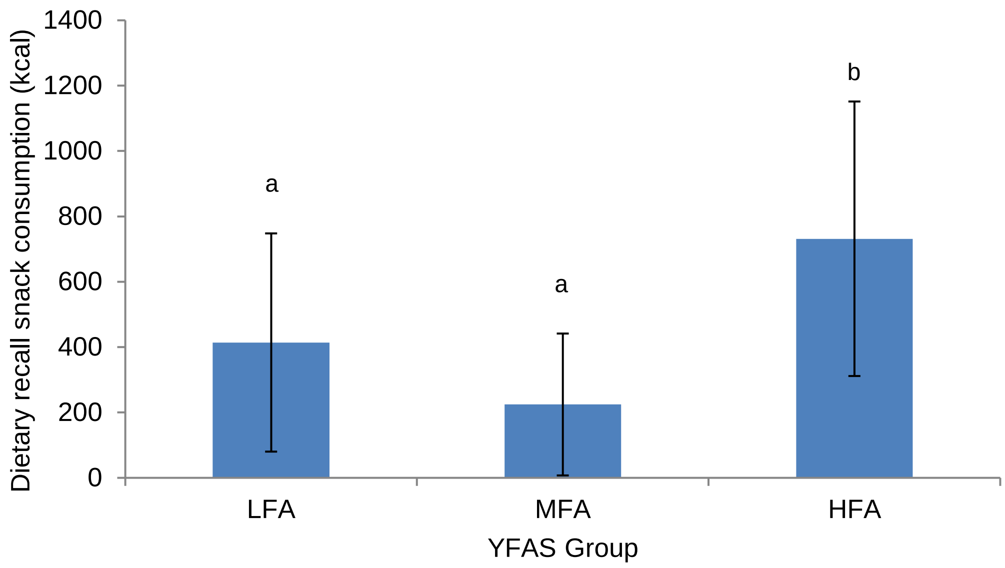


Figure 32. Energy intake (kcal) from snacks in the dietary recall session in the LFA, MFA and HFA groups. Note: lines denote standard error. Unalike letters indicate significant difference.

7.4.6 24-hour dietary recall macronutrient consumption

Percentage dietary intake from the 24-hour DR session was examined in order to explore differences in macronutrient consumption across YFAS groups. One-way ANOVAs revealed no differences in percentage consumption of protein ($p = .32$) or carbohydrate ($p = .06$), but a significant difference in percentage consumption of fat ($p < .05$).

Independent samples *t*-tests revealed that the HFA (M: 39.85) group consumed more percentage fat compared to MFA (M: 32.20) and LFA (M: 34.23, both $p < .05$). These results are depicted in *Figure 33*.

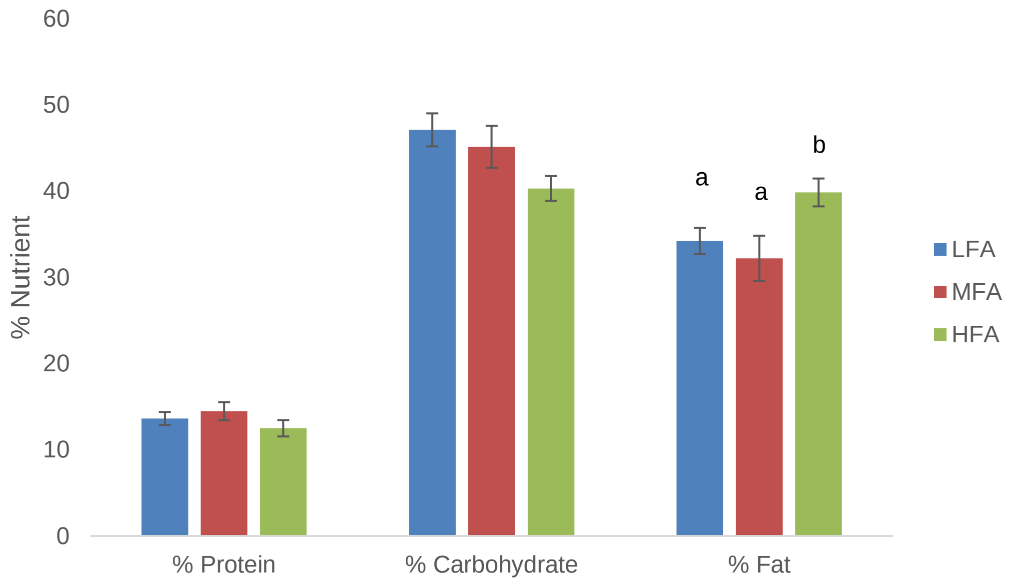


Figure 33. Macronutrient consumption (grams) across the 24-hour dietary recall session in the LFA, MFA and HFA groups. Note: lines denote Standard Error. Unalike letters indicate significant difference (per macronutrient).

7.4.7 Comparison of energy intake across TM and DR sessions

In order to assess any differences in calorie consumption across YFAS groups in the breakfast, lunch, dinner and snack eating episodes, repeated measures ANOVAs were conducted.

7.4.7.1 Breakfast

The results revealed no significant difference between calorie intake at breakfast across the TM and DR sessions (p =.11), nor an interaction between calorie intake at breakfast and YFAS group (p =.78).

7.4.7.2 Lunch

At lunch, the analyses revealed a significant effect of methodology on calorie intake at lunch ($F(1, 31) = 20.70$, p <.001, $\eta_p^2 = .40$), whereby across all YFAS groups, participants consumed more calories at lunch in the TM session (M: 779.05) compared to the DR session (M: 592.18, p <.001).

There was a significant interaction between lunch session and YFAS group (F(2, 31) = 5.48, *p* <.01, η_p^2 = .26), whereby, in the LFA group, participants ate more calories in the TM session (M: 731.14) compared to the DR session (M: 588.32, *p* <.05) and in the MFA group, participants ate more in the TM session (M: 920.80) compared to the DR session (M: 50.62, *p* <.001). This effect was absent in the HFA group in that there was no significant difference in calorie intake at lunch between the TM and DR sessions in this group. These results are demonstrated in *Figure 34*.

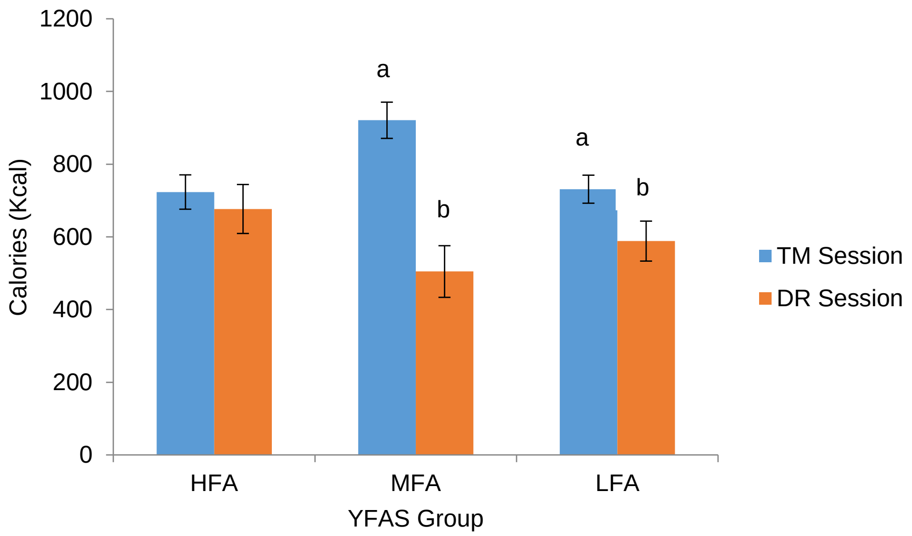


Figure 34. Calorie (Kcal) consumption at lunch across the Test Meal (TM) and Dietary Recall (DR) sessions in the LFA, MFA and HFA groups. Note: lines denote Standard Error. Unalike letters indicate significant difference (per group).

7.4.7.3 Dinner

The results revealed no significant difference between calorie intake at dinner across the TM and DR sessions (*p* =.15), nor an interaction between calorie intake at dinner and YFAS group (*p* =.07).

7.4.7.4 Snacks

There was a significant difference in calorie intake from the snacks across the TM and DR sessions (F(1, 31) = 5.18, *p* <.05), whereby participants ate more calories from snacks in the TM session (M: 564.40) compared to DR (M: 457.26).

There was a significant interaction between calorie intake from snacks across methods and YFAS group ($F(2, 31) = 4.10$, $p < .05$), whereby the MFA group ate significantly more calories from snacks in the TM session (M: 607.61) compared to DR session (M: 224.43, $p < .01$), as demonstrated in *Figure 35*.

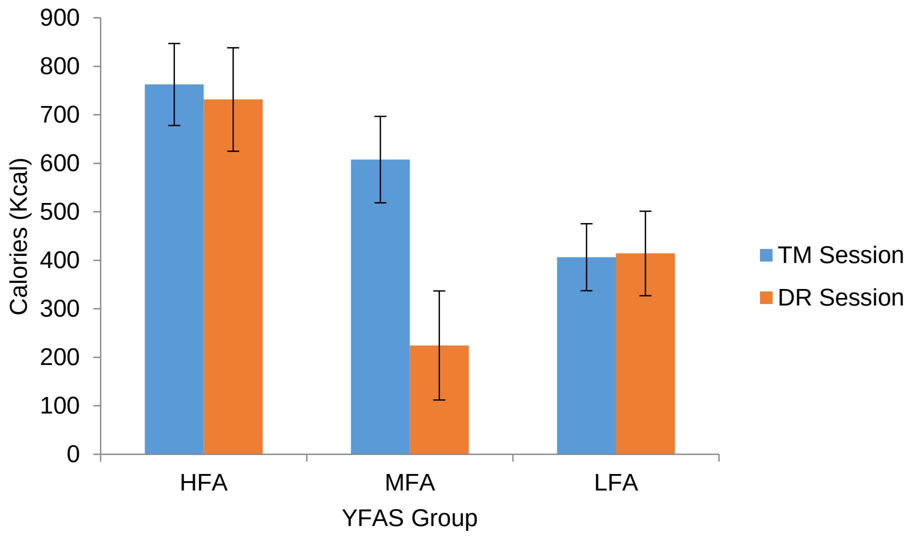


Figure 35. Calorie (Kcal) consumption from snacks across the Test Meal (TM) and Dietary Recall (DR) sessions in the LFA, MFA and HFA groups. Note: lines denote Standard Error. Unalike letters indicate significant difference (per group).

7.4.8 Food hedonics

7.4.8.1 Explicit liking

Food hedonics were explored using the LFPQ results. There was a significant main effect of motivational state on ratings of explicit liking ($F(1, 31) = 57.86$, $p < .001$, $\eta_p^2 = .65$), whereby explicit liking was greater in the fasted (M: 59.34) compared to fed (M: 39.60) state. There was no main effect of YFAS group ($p = .13$), nor an interaction between YFAS group and motivational state ($p = .29$) on explicit liking.

There was a significant main effect of food category on ratings of explicit liking ($F(2.42, 75.13) = 8.86$, $p < .001$, $\eta_p^2 = .22$), such that explicit liking was significantly greater towards HFSW (M: 55.94) compared to HFSA (M: 44.15, *p*

<.05) and LFSA (M: 42.82, p <.01). Explicit liking was also greater for LFSW (M: 54.97) compared to HFSA (p <.05) and LFSA (p <.01). There was a significant interaction between YFAS group and food category (F(4.85, 75.13) = 2.89, p <.05, η_p^2 =.16), in that, in the HFA group, explicit liking was significantly greater for HFSW and LFSW foods compared to LFSA (p <.01 and p <.05, respectively). This effect was absent in the MFA and LFA groups. These results are depicted in *Figure 36*.

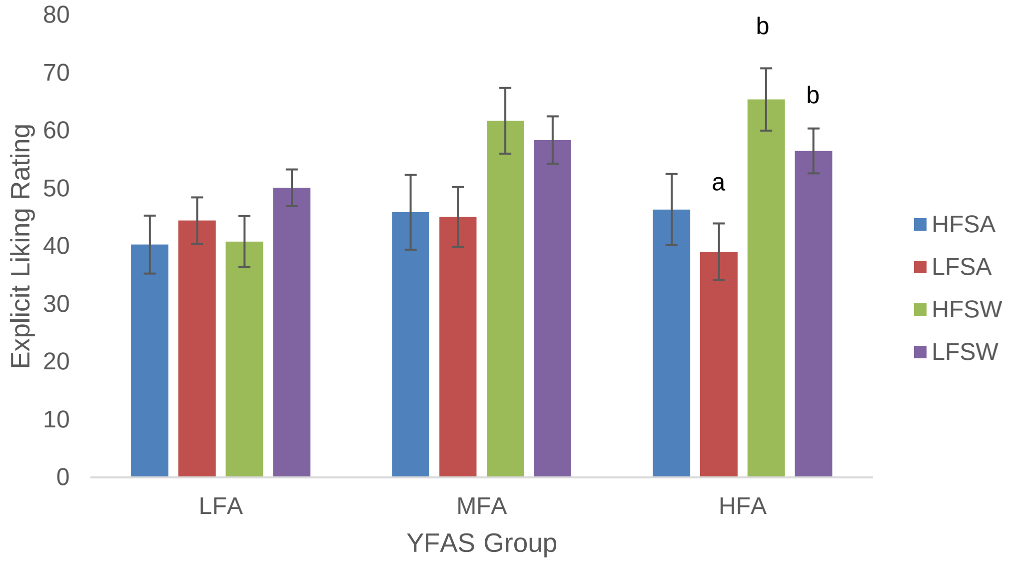


Figure 36. Explicit liking ratings for each food category across YFAS groups. Note: lines denote standard error. Unalike letters indicate significant difference.

There was a significant interaction between motivational state and food category (F(1.92, 59.51) = 10.34, p <.001, η_p^2 = .25), such that, in the fed state only, ratings of explicit liking were significantly greater for LFSW and HFSW compared to HFSA and LFSA (all p <.01). There was no interaction between YFAS group, motivational state and food category (p =.85).

7.4.8.2 Explicit wanting

There was a significant main effect of motivational state on explicit wanting ratings (F(1, 31) = 52.48, p <.001, η_p^2 = .63), such that explicit wanting was significantly greater in the fasted (M: 56.24) compared to fed (M: 32.26) state.

There was no main effect of YFAS group (*p* =.61), nor an interaction between YFAS group and motivational state (*p* =.50) on explicit wanting.

There was a significant main effect of food category on explicit wanting (F(2.13, 66.14) = 5.34, *p* <.01, η_p^2 =.15), whereby explicit wanting was significantly greater towards LFSW (M: 49.25) compared to LFSA (M: 38.58, *p* <.05). There was no interaction between YFAS group and food category (*p* =.21).

There was a significant interaction between motivational state and food category (F(1.97, 61.01) = 8.67, *p* <.01, η_p^2 =.22), in that, in the fed state, explicit wanting was greater towards LFSW (M: 43.19) compared to HFSA (M: 22.92, *p* <.001) and LFSA (M: 23.33 *p* <.001), and greater in HFSW (M: 39.59) compared to HFSA (*p* <.01) and LFSA (*p* <.05). There was no interaction between YFAS group, motivational state and food category (*p* =.69).

7.4.8.3 Implicit wanting

There was no main effect of YFAS group (*p* =.50), nor an interaction between YFAS group and motivational state (*p* =.08) on implicit wanting.

There was a significant main effect of food category on ratings of implicit wanting (F(2.41, 74.66) = 6.80, *p* <.01, η_p^2 = .18), such that implicit wanting was significantly greater for HFSW (M: .17) and LFSW (M: .14) compared to HFSA (M: -.26, both *p* <.01). There was a significant interaction between food category and YFAS group (F(4.82, 74.66) = 3.03, *p* <.05, η_p^2 = .16), in that, in the MFA group, implicit wanting was significantly greater for LFSW (M: .14) compared to HFSA (M: -.45, *p* <.05). In the HFA group, implicit wanting was significantly greater for HFSW (M: .29) and LFSW (M: .26) compared to LFSA (M: -.49, both *p* <.05). These results are demonstrated in *Figure 37*.

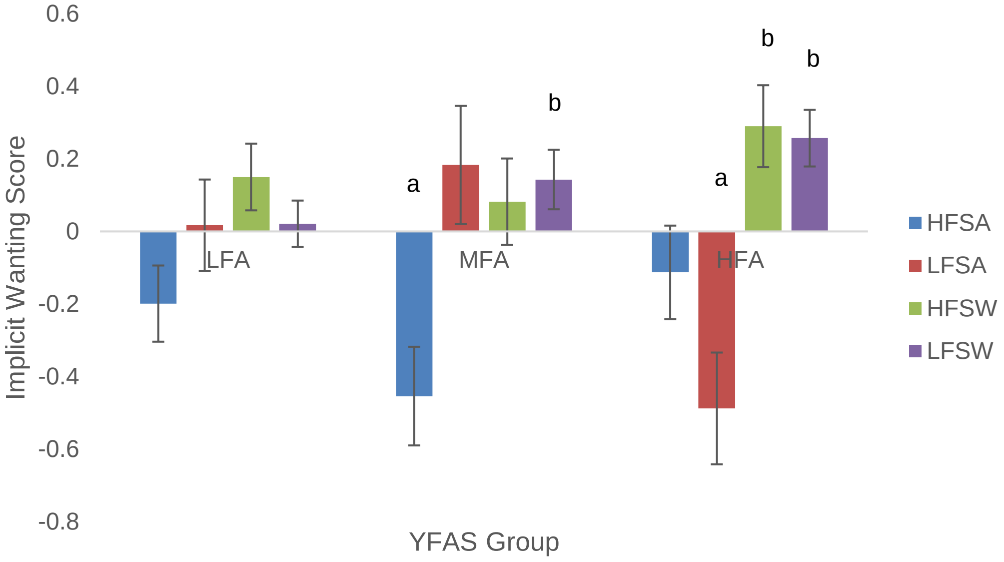


Figure 37. Implicit wanting for each food category across YFAS groups. Note: lines denote standard error. Unalike letters indicate significant difference (per group). A positive score represents greater implicit wanting.

7.5 Discussion

Given the hedonic drivers of drug intake, to which FA has been compared to, an investigation into the influences of hedonic processes of eating behaviour was conducted. As the results of the previous chapter (Chapter 6) revealed no differences in homeostatic appetite response across YFAS scores, the present chapter instead aimed to investigate the hedonic food preferences and hedonic processes under laboratory and free-living conditions in individuals varying in scores on the Yale Food Addiction Scale (YFAS). Specifically, macronutrient and energy intake across a combined 24-hour laboratory assessment and 24-hour free-living investigation of eating behaviour were analysed, hypothesising that individuals in the highest tertile of YFAS scores will consume more energy and fat compared to low YFAS-scorers under both methodologies. Secondly, differences in explicit liking, explicit wanting and implicit wanting towards high and low fat, sweet and savoury foods were analysed, utilising the LFPQ before and after an *ad libitum* lunch test-meal. It was hypothesised that the highest tertile of YFAS scorers will display increased explicit and implicit wanting for high fat foods according to the LFPQ, yet there will be no differences in explicit liking of high fat or sweet foods across YFAS tertiles. Finally, the Control of Eating Questionnaire (CoEQ), was used to analyse craving across tertiles of YFAS scores, hypothesising that individuals in the highest tertile would display the strongest cravings compared to lower tertiles.

Analysis of the sample characteristics revealed that the YFAS tertiles did not differ on any anthropometric or demographic variables, supporting the findings of Chapter 6, whereby no differences in physiological characteristics were revealed across individuals differing in YFAS scores. Although there was a non-significant trend towards greater fat mass in the HFA group, it must be considered whether this could be a matter of low power and may have been significant in a larger sample. The findings reported by Pedram et al. (2013) – that individuals characterised using the dichotomous YFAS criteria had significantly more body fat and trunk fat compared to Non-FA subjects – could not be supported at present, yet the increased body fat in HFA individuals could be meaningful and warrants further investigation.

Differences in eating behaviour traits were revealed across YFAS tertiles, with the HFA group displaying the highest levels of binge eating, restraint, disinhibition, hunger and craving for sweet foods, according to the BES, TFEQ and CoEQ, respectively. Such results support the hypothesis that the highest tertile of YFAS scores would display a greater degree of craving compared to lower tertiles. This finding is supported by Polk et al. (2016) who reported that increased craving for highly ‘processed’ foods was greater in high compared to low YFAS-scoring individuals. Interestingly, significant differences between YFAS tertiles was only revealed in ‘craving for sweet foods’ subcategory of the CoEQ. It is well observed that sweet foods are often craved frequently, and perhaps individuals with high scores on the YFAS are more susceptible to these cravings. However, in support of the opinion of Rogers and Smit (2000), although food cravings are often reported in parallel with supposed ‘addictive’ eating behaviours, they can also occur independently and may rather be an normal expression of appetite control (Blundell et al., 2014).

Chapter 6 also revealed greater binge eating and disinhibition in the highest tertile of YFAS scores, whilst significant positive correlations between YFAS ‘symptom count’ and the BES, TFEQ and CoEQ craving for sweet subscale were reported in Chapter 4. These results demonstrate a degree of problematic eating traits in individuals with increasing YFAS scores as such correlates are consistently revealed in FA literature (see Chapter 2). However, as described in Chapter 4, such traits are not unique to the concept of FA and already well documented in common clinically-recognised eating behaviour pathologies, namely binge eating. In addition, it is yet to be conclusively established whether these psychological traits are reflected in actual eating behaviour.

The present results revealed that these differences in eating behaviour traits were not reflected in subjective sensations of appetite. No differences between YFAS tertiles in measures of hunger, fullness, desire to eat or prospective consumption were revealed, with each group responding to the satiating effects of meal consumption to a similar degree across the TM day. Similar results were reported in Chapter 6, in that YFAS group had no interaction with ratings of appetite sensations across the day in any of the three preload conditions. The possibility that this lack of effect could be attributed to misreporting of VAS data must be considered, though previous research has demonstrated that VAS data is reliable and valid (Gibbons et al., 2011; Stubbs et al., 2000).

7.5.1 Do individuals across tertiles of YFAS scores differ in their free choice of energy and fat consumption?

Whether the aforementioned problematic eating behaviour traits would be displayed in actual eating behaviour was therefore examined across a combined laboratory and dietary recall assessment. The results revealed that, in the laboratory-based test meal day, no differences in EI at the *ad libitum* breakfast between YFAS groups were revealed, yet differences between groups at lunch, dinner and afternoon snacks were evident. Interestingly, at lunch, the MFA group consumed the most energy out of the three tertiles. From the afternoon snacks, however, the HFA and MFA groups consumed more energy compared to LFA, and at dinner the HFA group consumed the most energy compared to MFA and LFA. Such results reveal an increase in EI with increasing YFAS score across afternoon and evening eating episodes. However, the highest tertile of YFAS scores seemed to reduce their intake at lunch compared to the MFA group. One possibility for this effect proposes that self-regulation tends to be reduced later in the day (Boland, Connell, & Vallen, 2013). Therefore, those individuals who demonstrate high levels of restraint at breakfast and lunch by restricting their intake – such as those individuals with high YFAS scores – may subsequently overconsume in the afternoon and evening, when self-regulation resources have been depleted (Muraven & Baumeister, 2000). That notwithstanding, the findings of Chapter 6 revealed no differences across YFAS groups in EI at dinner. Therefore it should be qualified that under the conditions of the present chapter, whereby individuals had access to a choice of palatable and high energy foods, self-regulation may break down in individuals with high scores on the YFAS.

When the intake of snack foods in the laboratory-based test meal day were analysed, differences in consumption of high and low fat, sweet and savoury snack foods were revealed, such that all subjects consumed more energy from HFSW snacks compared to the other food categories. Across YFAS groups specifically, the HFA group consumed the most energy from HFSW foods, compared to the other food categories and YFAS groups. The MFA group consumed more energy from LFSW foods compared to the LFA group but not compared to the other food categories.

Similarly, in the free-living dietary recall assessment, no differences in energy intake at breakfast, lunch or dinner across YFAS groups were revealed, yet the HFA group consumed significantly more energy from snack foods across the day compared to the other groups. Indeed, the HFA group consumed over three times as much energy from snack foods as the MFA group, and almost twice as much as the LFA group, across the day. These results are supported by a study by Davis et al. (2014) who found that YFAS-defined ‘food addicts’ displayed no reduction in snack food consumption when administered a dopamine agonist which typically suppresses food intake. Such results suggest a possible susceptibility towards hedonically-driven overconsumption in individuals scoring highly on the YFAS, possibly mediated by impaired dopamine signalling.

It appears that there is a non-linear relationship between YFAS scores and EI at meal times, yet a clear susceptibility towards overeating of snack foods is evident in the highest tertile of YFAS scorers. Similar results have been demonstrated in overweight individuals and those engaging in binge eating behaviour. For example, in a primary analysis of the current data set, grouping subjects into obese and lean binge eaters and non-binge eaters, Dalton et al. (2013b) reported that obese binge eaters consumed more energy from snacks during the laboratory-based test meal day, particularly from high fat sweet foods. Comparable results were also reported by Dalton et al. (2013a).

Though no differences in body mass or body composition were revealed in the present sample, excessive consumption of snack foods has been reported to be associated with increasing weight and fatness over time (Marmonier, Chapelot, & Louis-Sylvestre, 2000; McCrory et al., 1999; Phillips et al., 2004). Dalton et al. (2013a) found that obese participants ate significantly more snack foods compared to lean subjects, suggesting that individuals with increased snack food consumption could be at risk of weight gain. Conversely, however, Masheb and Grilo (2006) found that increased snack intake was associated with lower body weight. Therefore it may not be snacking *per se* which contributes to weight gain, but the types of snacks consumed. For example, two or three planned snacks of low energy density alongside three meals per day is a structured meal intake pattern and is often recommended as treatment for individuals with Binge Eating Disorder (C. G. Fairburn, 1993). The preference for HFSW snack foods in the HFA group, therefore, means that the HFA group may be particularly susceptible to weight gain.

In order to further explore this, the macronutrient intake across groups was assessed at individual eating episodes and across the 24-hour dietary recall assessment. The results revealed that the tertiles did not differ in their percentage consumption of protein or carbohydrate but the HFA group consumed a greater percentage of fat compared to MFA and LFA. These results are comparable to those reported in Chapter 5, whereby foods higher in fat and saturated fat were more likely to be rated as having both ‘addictive potential’ and contributing to problematic eating behaviours, across the whole sample. These findings are further supported by the aforementioned research by Pedram and Sun (2014); Pedram et al. (2013) and Pursey et al. (2015), who reported greater consumption of energy from fat in ‘food addicted’ subjects, as well as positive associations between fat consumption and YFAS score.

Such results have led some authors to conclude that high fat foods should therefore be considered ‘addictive agents’ (Schulte et al., 2015) which prompt so-called ‘addictive’ responses in high YFAS-scoring individuals (Avena et al., 2008; Gearhardt, Davis, et al., 2011). However, comparable results are found amongst individuals with other existing problematic eating behaviours. For example, Yanovski et al. (1992) found that obese subjects with Binge Eating Disorder (BED) consumed a greater percentage of energy from fat at a laboratory meal which they were instructed to binge eat. Meanwhile, Raymond, Neumeyer, Warren, Lee, and Peterson (2003) reported that subjects with BED ate significantly more energy from fat on binge days. Furthermore, Gendall, Joyce, Sullivan, and Bulik (1998) found that restrained eaters craved high fat foods more frequently. These findings suggest that overconsumption of high fat foods is not unique to individuals with high scores on the YFAS, but may be a common trait of many individuals with problematic eating behaviour.

Interestingly, no differences between YFAS groups in grams of carbohydrates or sugar consumed were revealed, despite propositions that high carbohydrate foods are implicated in ‘addictive’-like eating behaviours (Christensen, 2007; Schulte et al., 2015; Spring et al., 2008) and that sugar may have a specific role in the development of FA (Avena, Bocarsly, et al., 2012; Colantuoni et al., 2002; Rada et al., 2005). Such results are similar to the findings of Markus et al. (2017) who reported that only 5% of subjects reported FA symptoms specifically for high sugar foods. Instead, 25-30% of subjects reported problematic eating behaviours towards high fat sweet or high fat savoury foods. It seems that foods high in fat content, possibly in combination with carbohydrate or sugar are most strongly implicated in overeating (Dalton & Finlayson, 2014).

As previously mentioned, however, overconsumption of high fat foods does not constitute an ‘addictive’ response. High fat foods are often highly palatable, therefore the increased consumption of such foods can be attributed to palatability and food preferences, rather than any degree of ‘addictive’ behaviour (Finlayson, 2017; Ziauddeen & Fletcher, 2013). Instead of applying a universal label of so-called food addiction, perhaps the YFAS is identifying individuals with strong preferences for highly palatable foods, particularly high fat sweet snack foods; an observation which is not new, nor which requires a unique ‘diagnosis’ of FA (Blundell & Finlayson, 2011).

7.5.2 Do individuals across tertiles of YFAS scores differ in ratings of explicit liking, explicit wanting or implicit wanting?

Ratings of explicit liking, explicit wanting and implicit wanting of the 16 food items across 4 different food categories (HFSA, LFSA, HFSW, LFSW) according to the LFPQ, in response to an *ad libitum* lunch meal across low, moderate and high-scoring YFAS tertiles were explored. The results revealed that consumption of an *ad libitum* lunch meal influenced ratings of explicit liking and explicit wanting across the whole sample. Specifically, ratings of explicit liking and explicit wanting were greater pre- compared to post-lunch. Such results suggest that satiation diminishes explicit liking and wanting.

When YFAS scores in this sample were grouped according to a tertile split, it was revealed that the HFA group had higher explicit liking and implicit wanting of HFSW and LFSW foods, compared to LFSA. Similarly, the MFA group had greater implicit wanting of LFSW compared to HFSA foods. These results suggest that increasing YFAS score is associated with a preference towards high and low fat sweet foods, driven by both explicit liking and implicit wanting. Such findings undermine the hypothesis that liking will remain stable across tertiles of YFAS scores and cannot, therefore, support the idea that hedonic dysregulation (of liking versus wanting) may be responsible for overconsumption in ‘food addicted’ individuals (Davis & Loxton, 2014). Interestingly, however, the preference towards LFSW foods appears to undermine the conclusion of Chapter 5: that energy density is most implicated in problematic eating behaviours or ‘addictive potential’. Clearly low fat foods are low in energy density, so perhaps sweetness is the primary driver of food preferences, even in the absence of energy density.

Similar results have been reported by Dalton et al. (2013a) who found that in an obese binge eating group, implicit wanting for sweet foods increased in the post-meal trial, compared to the fasted trials, whilst this effect was absent in the lean binge, lean non-binge and obese non-binge groups. In addition, Finlayson, Bordes, Griffioen-Roose, de Graaf, and Blundell (2012) reported that individuals with high levels of disinhibition displayed greater explicit liking for all food categories, as well as an increased implicit wanting for HFSW foods, compared to individuals with low levels of disinhibition. Moreover, Dalton et al. (2013b) reported that obese binge eaters displayed the greatest implicit wanting for high and low fat sweet foods. Furthermore, this study demonstrated that preferences towards high fat sweet foods in this obese binge eating group were associated with increased consumption of these types of foods in snack and meal format. Such results suggest that this pattern of preference for high fat sweet foods may be a common trait amongst individuals susceptible to overeating (Dalton et al., 2013a; Finlayson et al., 2011), including binge eaters and those with high levels of disinhibition, and do not necessarily reflect an ‘addictive’ vulnerability.

7.5.3 Limitations

The limited generalisability and ecological validity of laboratory-based test meal assessments was addressed by combining this methodology with a free-living dietary recall assessment in the current chapter. This provided an insight into the differing behaviours of participants across laboratory-based and free-living settings. Furthermore, as the purpose of the DR session was blinded to participants until they arrived for the session, subjects were unlikely to adjust their EI for the purpose of the study (Block, 1982).

Significant correlations in the overall energy intake and snack food intake between the laboratory-based test meal and free-living dietary recall sessions suggest that the constraints of the laboratory setting had minimal impact on the normal eating behaviour of the participants. The differences in consumption at meal times between the two assessment methods could likely be due to the unfamiliarity and non-habitual nature of the laboratory-based meals. The significant correlation between snack food consumption in the laboratory-based and dietary recall sessions are of particular note as snack foods are often forgotten in dietary recall techniques (Poppitt, Swann, Black, & Prentice, 1998). These results demonstrate the efficacy of the AMPM method for recalling snack food consumption (Conway, Ingwersen, Stout, & Moshfegh, 2001).

In addition, as the present chapter presented a secondary analysis of a data set aimed to explore the eating behaviour of obese and lean individuals varying in BES scores, the tertile split of YFAS scores to form the groups in the present analysis were not matched for age or BMI. Finally, physical activity during the testing sessions was not monitored, therefore any compensatory effects of increasing energy expenditure through PA could have occurred to offset any increases in EI. Future research would benefit from objectively monitoring PA throughout the testing procedure, using such techniques as those described in Chapter 6.

7.5.4 Conclusions

To conclude, the results of the present chapter demonstrate that increasing YFAS score is associated with a preference towards and greater consumption of HFSW snack foods as well as increasing consumption of fat. However, no differences in consumption of carbohydrates were revealed, suggesting that the YFAS may identify frequent snackers, but does not implicate carbohydrates *per se* as promoting possible compulsive eating behaviours. As overconsumption of high fat and high fat sweet foods may promote changes in weight and body fat mass, those individuals who present a degree of uncontrolled overeating would benefit from reducing their consumption of high fat and sweet foods and snacks to maintain a healthy body weight.

With regards to food hedonics, the results from the LFPQ revealed that the HFA group demonstrated enhanced explicit liking and implicit wanting of HFSW and LFSW foods, compared to LFSA. These results suggest that increasing YFAS score is associated with a preference towards sweetness, both with or without the vehicle of fat. In HFSW foods, the fat content enhances the appeal of sweetness leading to a higher intake of these foods. However, in LFSW foods, sweetness *per se* appears to be sufficient in driving these preferences, though the foods defined as 'low fat' according to the LFPQ still contain up to 20% energy from fat, which may be contributing to the enhanced preferences as in the case of HFSW foods. Nevertheless, this preference is driven by both explicit liking and implicit wanting, thus it cannot be concluded that so-called food addiction is associated with the type of hedonic dysregulation associated with drug abuse.

In addition, the highest tertile of YFAS scores demonstrated increased cravings for sweet foods compared to lower tertiles, demonstrating an increased susceptibility towards craving foods in individuals with high YFAS scores. It appears that in these individuals, such cravings are frequently converted into actual eating behaviour, due to their relative overconsumption of high fat sweet snack foods. Therefore, strategies to reduce cravings could be useful to minimise overconsumption.

However, the overconsumption of certain nutrients reported in this chapter cannot be assumed to represent any degree of 'addictive' tendencies towards these foods. High fat foods and HFSW snack foods are consistently implicated in general overconsumption, an expected response given the high palatability of such foods. Therefore, individuals scoring highly on the YFAS are unlikely to be demonstrating a type of 'addictive' behaviours, but simply possess strong preferences towards high fat foods and high fat sweet snacks.

It can be concluded that applying the term 'food addiction' to all individuals who overconsume high fat foods, sweet foods or snack foods is inappropriate, especially given the availability of such foods in the modern environment. Instead, the focus should be on promoting healthy eating behaviours, particularly in subjects prone to binge eating behaviour.

Summary

- Under conditions of food choice and access to palatable foods, individuals in the highest tertile of YFAS scores consumed more energy at dinner, from snacks and percentage fat compared to lower tertiles.
- In terms of food hedonics, the LFPQ revealed that the HFA group had greater explicit liking and implicit wanting of HFSW and LFSW foods compared to other tertiles and food categories, whilst the HFA group displayed increased craving for sweet foods.
- Increasing YFAS score is associated with an increased preference towards, craving for, and greater consumption of high fat foods and high fat sweet snacks, but this preference should not be interpreted as evidence for an ‘addiction’ towards these foods.

Chapter 8

General discussion

The work presented in this thesis comprises a sequence of empirical investigations into the concept of 'food addiction' (FA), its validity, its usefulness and its potential role in overeating and obesity. This work was conducted in response to the uncritical assumption that obesity is attributable to an 'addiction' to highly palatable foods or ingredients, and that the degree of this 'addiction' should be quantified in individuals using the self-report Yale Food Addiction Scale (YFAS). Through the accumulation of a systematic literature review and five experimental chapters, the specific aims of this thesis were:

1. To critically review the literature employing the Yale Food Addiction Scale and related constructs (e.g. eating addiction) in the general population and relevant subgroups (**Chapter 2**)
2. To examine the psychometric properties of the YFAS and assess its validity as an instrument to measure and 'diagnose' so-called 'food addiction' (**Chapter 3**)
3. To examine whether alleged FA is a condition distinct from existing eating behaviour phenomena (especially binge eating) in the general population and is associated with significant physical or psychological distress or addictive personality characteristics (**Chapter 4**)
4. To explore whether individuals with a YFAS diagnosis are distinguishable by the identification of specific targeted food substances as 'problematic' or carrying 'addictive potential' (**Chapter 5**)
5. To investigate whether individuals with high scores on the YFAS exhibit differences in homeostatic appetite control under a laboratory-controlled energy intake paradigm (**Chapter 6**)
6. To examine the ways in which the YFAS is related to food preferences, food reward (liking and wanting) and experiences of food cravings in a laboratory and free-living setting (**Chapter 7**)

8.1 Overview of key findings

8.1.1 Chapter 2

In Chapter 2, a review of the literature utilising the YFAS in examining FA was systematically conducted. Using predefined search criteria, forty empirical studies were included for review. The results (which are presented in Appendix A) revealed a four to five times greater prevalence of FA in overweight and obese samples compared to the prevalence in the general population, exceeding the two- to three-fold increase reported by Avena, Gearhardt, et al. (2012) and the two-fold increase described in a systematic review and meta-analysis by Pursey, Stanwell, Gearhardt, et al. (2014). However, the associations between the YFAS and BMI were less clear. Seven studies reported positive associations between YFAS score and BMI in a range of samples, whilst no associations between the YFAS and BMI was reported in five of the reviewed studies.

This chapter also revealed a consistently amplified prevalence of YFAS-defined FA in individuals with Binge Eating Disorder (BED), and an even higher prevalence in subjects with Bulimia Nervosa (BN), as well as reliable associations between YFAS scores and binge eating behaviour across multiple studies and samples. Such results suggest that one or more of the YFAS criteria for FA may represent a behaviour endorsed by individuals with elevated BMIs or binge eating symptomatology.

Mixed results regarding the relationship between YFAS “diagnoses” and psychological wellbeing were revealed in Chapter 2. For example, some studies reported a positive association between depression and YFAS score whilst other studies failed to replicate this association. Additional mixed results concerning the associations between YFAS scores and substance use disorders were uncovered, whilst the associations between the YFAS and weight loss outcomes were also inconsistent. For example, Burmeister et al. (2013) reported a reduced weight loss in individuals with YFAS-defined FA, yet Lent et al. (2014) described no association between YFAS score and weight loss success.

However, this chapter uncovered some critical flaws in the arguments supporting FA. For example, despite the increased prevalence rates of YFAS “diagnoses” in samples of overweight or obese individuals or those with BED, such findings do not validate the existence of food addiction as a novel behavioural phenotype which explains overconsumption. In particular, the high YFAS prevalence rates identified in individuals who engaged in binge eating behaviour raises the question over whether FA contributes any important information to assist in the understanding of binge or over-eating behaviour.

Furthermore, much of the literature reviewed in this chapter assumed that FA is a quantifiable construct, measurable by the YFAS, despite limited data in favour of this perspective. Crucially, as described in the introductory chapter of this thesis, Chapter 2 also highlighted that FA literature is hindered by the lack of formal definition for this proposed condition. This issue will be difficult to resolve whilst the YFAS continues to be employed as a proposed diagnostic tool, due to the circularity of its existence. Currently the only quantification of a ‘food addict’ is a high score on the YFAS, yet the only definition of someone who has a high score on the YFAS is “a ‘food addict’”. Only by identifying recognisable clinical characteristics of the supposed FA phenotype will this circularity be broken.

To ensure the literature included within this thesis was up-to-date, an amendment to this chapter was undertaken to review any papers which had been published since the review was first conducted until June 2017. The results of this review (which are presented in Appendix B) supported those of the primary review, indicating a similarly positive relationship between YFAS scores and binge eating behaviours. However, the increased prevalence of FA amongst overweight and obese samples was not replicated across the whole of the literature, with one study reporting a small (6.70%) prevalence of FA in weight loss treatment-seeking obese individuals, whilst another study reported a prevalence of FA of 34.10% in a comparable sample. In a sample of overweight and obese children and adolescents, however, a prevalence of FA of 7.10% was revealed, indicating impaired eating behaviour traits in children as young as 10 years of age.

Unlike the original systematic review, the amendment revealed a more clear relationship between YFAS scores and poor psychological wellbeing, with a consistent association between YFAS score and depressive symptoms, anxiety, reduced quality of life and emotion regulation. One novel finding included the administration of the YFAS to a sample of adolescent psychiatric inpatient females. In this sample, 16.50% met the YFAS criteria for FA, whilst 42.50% of these individuals patients met the criteria for an eating disorder (ED). YFAS score was significantly higher in ED patients, suggesting a non-linear relationship between FA 'diagnoses' and BMI.

A clear limitation of both reviews was the lack of independent objective measurement of behaviour of those individuals with high scores on the YFAS. In the original review only three studies employed the YFAS in studies of food intake behaviour. In the amended review, four studies employed such methodology. However, in two of these studies, the measure of food intake across individuals differing in YFAS score was not an outcome measure (Epstein et al., 2016; Imperatori et al., 2015). In the third, Richmond, Roberto, and Gearhardt (2017) investigated food intake across a laboratory-based dinner paradigm and an evening food recall assessment in children. Though the results suggested that younger children with higher scores on the YFAS-C consumed more energy at dinner and across the evening, the use of the YFAS in children is not yet validated, though such findings indicate that overeating behaviours are evident even in young children. The final study which included a measure of food intake revealed that 'self-perceived food addicts' consumed a greater amount of calories from high-fat food compared to 'non-perceived food addicts'. However, further analyses attributed these preferences to dietary restraint and disinhibition (Ruddock, Field, & Hardman, 2017), suggesting that FA, whether perceived or measured through the YFAS, is not directly influencing food intake. Given the limitations of the FA literature revealed in this chapter, the subsequent studies in the present thesis therefore aimed to administer the YFAS across a range of methodological platforms, including cross-sectional, survey-based studies, but also extending into laboratory and free-living assessments of eating behaviour, energy intake and energy expenditure.

8.1.2 Chapter 3

As revealed by the large amount of literature reviewed in Chapter 2, the YFAS appears to be forming a cornerstone of the literature on food addiction, yet the acceptance of this questionnaire into scientific literature appears to have occurred uncritically. In response to this, Chapter 3 investigated the psychometric properties of the YFAS using multiple methods of factor analysis in two large survey-based data sets. It was hypothesised that, given the extrapolation of the YFAS from the seven criteria for substance dependence according to the Diagnostic and Statistical Manual of Mental Disorders (DSM), plus an additional assessment of clinical impairment, the YFAS should present an eight-factor structure, rather than the one-factor structure identified in previous literature. Firstly, this one-factor structure was investigated using Confirmatory Factor Analysis (CFA) in a large data set, but the results revealed that the data had a poor fit of the model. Subsequently, a theory-driven, seven factor structure (reflecting seven of the YFAS criteria) was investigated using the same technique and was again found to be a poor fit according to goodness-of-fit indices. In response to this, a data-driven approach was utilised, employing Principal Components Analysis (PCA) with parallel analysis in a separate data set to explore which model best fit the data. The results revealed a two-factor model with an acceptable fit, explaining 35.15% of the variance in the data. Item analysis exposed items 4, 9, 10, 11 and 24 as having poor psychometric properties and were removed from the model. This model was validated using CFA in a separate data set, identifying a further two items (22 and 25) with poor factor loadings which were subsequently removed. The final two factors were tentatively interpreted as representing “drive to overeat” and “strength of food habits”. However, it can be noted that neither of these constructs appear to reflect any traits suggestive of an ‘addiction’, and demonstrated low internal reliability (Cronbach’s α = .67 and .58 respectively). This chapter concluded that the YFAS, though widely-administered and generally accepted uncritically by researchers, demonstrates weak psychometric properties and its results should be interpreted cautiously.

This conclusion represents an important issue surrounding the use of the YFAS in scientific literature. Psychometric scales assume that their underlying construct is “stable, quantifiable and measurable” (Blundell et al., 2014, p.218). The YFAS, however, does not clearly define or quantify the condition which it supposedly measures. Instead, by drawing upon the overlaps between certain features of overeating and the DSM-IV-TR criteria for substance use (as described in detail in Chapter 1), the only defining characteristics of FA are individuals' responses to the YFAS. As a result of this approach, no clear behavioural indicators or thresholds discriminating between a 'food addict' and the rest of the population have been identified. As food, unlike drugs, is consumed universally, clear thresholds which distinguish between use and misuse cannot be easily quantified, nor is there a clear point at which consumption transitions into an 'addictive' behaviour (Blundell et al., 2014; Ziauddeen & Fletcher, 2013). Instead, the YFAS has enforced its own severity thresholds which must be met in order to satisfy the criteria of a 'food addict' (Gearhardt et al., 2009b). Whilst reaching such thresholds must capture certain features of eating behaviour which are indeed maladaptive, questionnaire responses do not provide evidence for a stable condition and this approach should not be considered sufficiently comprehensive to warrant adopting an addiction-related perspective of overeating (Ziauddeen et al., 2012b).

8.1.3 Chapter 4

In light of this criticism of the YFAS, Chapter 4 aimed to explore whether any characteristics can be identified which are indicative of and unique to "food addiction". Furthermore, given the significant overlaps between YFAS-defined FA and binge eating identified in Chapter 2, the issue of whether such traits were separable from binge eating was investigated. Chapter 4 employed a large survey-based design to investigate the strengths and direction of the associations between the YFAS and Binge Eating Scale (BES) and psychometric measures of problematic eating behaviours, psychological wellbeing and addictive behaviours. It was hypothesised that if the YFAS is measuring a unique phenotype defined by characteristics which resemble an addiction, it should show stronger relationships with measures commonly revealed in substance abusers, particularly impaired psychological wellbeing and addictive behaviour traits, when compared to the BES.

As expected, the strongest correlation lay between the YFAS 'symptom count' and BES. Further correlation analyses identified that the BES correlated to a similar or even greater strength with all measures of eating pathology, psychological distress and addictive behaviour traits, compared to the YFAS. In subsequent analyses, the YFAS 'symptom count' and BES were added simultaneously as predictors in multiple regression models, in order to compare the individual ability of these variables in predicting scores on measures of problematic eating behaviour, psychological wellbeing and addictive behaviours. The results showed that, when controlling for the BES, the YFAS was a significant predictor of scores on all variables except the Control of Eating Questionnaire (CoEQ) Craving Savoury subscale and Eating Disorder Examination (EDE) Restraint subscale. Conversely, when the YFAS was controlled for in the model, the BES could significantly predict variance in all variables, including the CoEQ Craving Savoury subscale and EDE restraint subscale, suggesting that the BES can already appropriately account for the symptomatology proposed to be displayed by individuals with high scores on the YFAS. However, neither the YFAS nor the BES could predict a significant amount of variance in scores on the Drug Abuse Screening Test (DAST), despite vulnerability to substance abuse being a central concept of addiction.

This chapter concluded, therefore, that the YFAS is unable to identify any characteristics which could not already be accounted for by the BES. In addition, the weak associations between the YFAS and measures of traits central to addiction, such as impaired psychological wellbeing and vulnerability to alcohol or drug use, suggest that the YFAS is not measuring any patterns of eating behaviour which are ‘addictive’-like. Though the YFAS may not identify any unique traits of overeating when employing psychometric and questionnaire-based indicators of certain behaviours, few studies have provided an assessment of so-called FA symptomatology with regards to individual responsiveness to food cues and laboratory-based and free-living measures of eating behaviours. The subsequent chapters, therefore, aimed to address this limitation of FA literature.

8.1.4 Chapter 5

As discussed in Chapter 1, much of the literature investigating FA assumes that specific foods or ingredients are implicated in the development of so-called food addiction. In light of this, Chapter 5 utilised of a large sample of adults, employing a novel paradigm to explore their subjective perceptions of 70 food images, varying in energy density (ED) and macronutrient composition. The design assessed individuals’ perceived problems associated with the foods, as well as their subjective perceptions of each food’s ‘addictive potential’. By separating the sample according to a YFAS 'diagnosis' of FA, differences in these perceptions across individuals varying in their degree of YFAS symptomatology could be explored. The results from this chapter revealed that energy density was the objective attribute of the foods which correlated most strongly with ratings of problematic eating and addictive potential. Regression analyses supported this finding, indicating that foods with greater energy density were associated with higher ratings of both perceived problems and addictive potential, yet such findings were consistent across those individuals who met a YFAS 'diagnosis' of FA (FA group), and those who did not (Non-FA group). It was concluded from this chapter, therefore, that an increasing score on the YFAS is not able to distinguish individuals with a greater susceptibility towards perceiving foods as more problematic or more likely to have 'addictive potential'. Instead, the objective attribute of energy density seems to be the most important feature of foods which may encourage problematic (over-) eating behaviours, regardless of YFAS score.

Critically, however, such findings should not be interpreted as suggesting that highly energy dense foods possess an ability to induce any degree of 'addictive' behaviours. Rather, foods with a high ED are well-understood to promote overconsumption, impair satiety signalling and weaken appetite control across multiple samples (for example; Bell et al., 1998; Prentice & Jebb, 2003; Stubbs et al., 1995); and this overconsumption has been termed 'passive'. All individuals, particularly those with problematic eating behaviours should be encouraged to reduce their consumption of high ED foods as a strategy to maintain a healthy body weight.

Despite these findings, and the employment of a unique paradigm to measure food perceptions, in a similar manner to Chapter 4, this chapter remained limited by its cross-sectional and survey based design. In light of this, Chapter 6 and Chapter 7 employed laboratory and combined laboratory and free-living assessments of eating behaviour, respectively, to further investigate susceptibility to overconsumption across individuals varying in scores on the YFAS in relation to actual food intake.

8.1.5 Chapter 6

As Chapter 5 revealed, the energy load in foods is perceived to play a significant role in problematic eating behaviours. However, the proposed overlaps between overeating and drug taking would suggest that such maladaptive eating behaviours are driven solely by hedonic influences on appetite control. Therefore, homeostatic control over food intake should not differ across individuals ranging in YFAS scores, for a given body weight. In order to assess this, a comprehensive laboratory-based energy intake (EI) and energy expenditure (EE) paradigm with a variable energy preload manipulation was employed in Chapter 6. Following a preliminary analysis of anthropometrics, body composition, fitness level, habitual physical activity and eating behaviour traits, the homeostatic control of appetite in individuals across tertiles of YFAS 'symptom count' was assessed. The degree to which individuals compensated for the energy consumed in a high energy preload (HEP) by reducing intake from *ad libitum* lunch, dinner and evening snacks, compared to a low- or no-energy preload (LEP and NEP, respectively), was measured. The design involved limiting food choice and restricting the palatability of the test foods, in order to minimise the hedonic influences on appetite and focus on homeostatic drivers.

The results revealed that the YFAS tertiles differed in fitness and physical activity level, revealing that the highest tertile (HFA group) had a significantly lower VO_{2Max}, lower habitual physical activity (PA) level and fewer minutes of moderate-to-vigorous physical activity (MVPA), compared to the lowest tertile (LFA group). The HFA group also had significantly higher scores on psychometric measures of binge eating and disinhibition and a less positive mood compared to the moderate FA (MFA) and LFA groups. When presented with a covertly ED manipulated preload snack, all participants decreased EI at an *ad libitum* lunch meal to a greater extent following the HEP, compared to LEP or NEP conditions. However, this compensatory effect was acute, and a similar EI at the *ad libitum* dinner and evening snack episodes were revealed across all conditions, resulting in an increase in total daily EI in the HEP condition, compared to LEP and NEP. However, these compensatory mechanisms did not differ as a function of YFAS tertile, supporting the results of Chapter 5 that high energy density foods prompt overconsumption and may impair appetite control, regardless of individuals' scores on the YFAS.

It was concluded that many individuals appear to be insensitive to a covert manipulation of the energy of a preload in the short-term, irrespective of YFAS score, revealing that individuals with high scores on the YFAS do not appear to be any more susceptible to overconsumption compared to low scorers. However, the novel findings that individuals with high scores on the YFAS display lower habitual physical activity and fitness levels may make them vulnerable to an enhanced degree of appetite insensitivity and lower energy expenditure leading to weight gain in the long term. The higher body fat of the HFA group, though non-significant and despite the tertiles being matched for BMI, appears to support this suggestion.

This chapter aimed to address some of the methodological limitations of the previous studies within this thesis, as well as previous research into FA, by conducting a controlled laboratory study. However, the ecological validity of laboratory-based studies may be considered to be rather low. Furthermore, this study addressed only the homeostatic control of intake, rather than other processes such as the influence of hedonics. Therefore, Chapter 7 aimed to extend this research into the free-living setting and investigate hedonic features of appetite control.

8.1.6 Chapter 7

Whilst Chapter 6 revealed no differences in homeostatic control of intake in individuals in the highest tertile of YFAS scores, an alternative proposition suggests that so-called FA may be of greater similarity to the hedonic dysfunctions displayed by individuals with substance-based addictions. It was therefore hypothesised in Chapter 7 that individuals with high scores on the YFAS would display a hedonic preference towards highly palatable (high fat, sweet) foods, and display greater wanting of and craving for these foods, but not differing in their liking of these foods compared to lower-scoring individuals. This chapter employed a combined 24-hour laboratory-based test meal (TM) paradigm and 24-hour free-living dietary recall (DR) assessment, as well as a behavioural paradigm developed to assess implicit and explicit wanting and implicit liking (the Leeds Food Preference Questionnaire; LFPQ).

The sample of 34 females varied in BMI and were split into tertiles according to YFAS score (HFA, MFA, LFA). The results revealed that, similar toChapter 6

Chapter 6, the HFA group had significantly higher binge eating, restraint, disinhibition and hunger, according to psychometric measures of eating behaviour, as well as greater craving for sweet foods compared to the LFA or MFA groups. As concluded inChapter 4 Chapter 4, individuals with the highest scores on the YFAS do appear to possess a range of more severe maladaptive eating behaviour traits in comparison to individuals with lower scores.

Though no significant differences between YFAS groups in ratings of appetite sensations were revealed, the MFA group consumed more energy at lunch compared to HFA and LFA, the HFA group consumed more energy at dinner compared to MFA and LFA, whilst both HFA and MFA consumed more energy from the afternoon snacks compared to LFA in the TM session. In the DR session, however, no differences in EI at breakfast, lunch or dinner were revealed between groups. These differences in eating behaviour across the two methodologies could possibly be a result of spontaneous overeating in the TM session, an effect commonly associated with *ad libitum* meal consumption (Larson, Rising, Ferraro, & Ravussin, 1995).

Of particular interest, however, were the differences in snack food consumption across groups. In the TM session, HFA consumed significantly more energy from HFSW snacks compared to MFA and LFA and the other food categories, whilst in the DR session, the HFA group consumed significantly more energy from snack foods compared to MFA and LFA. It appears as though the HFA group may restrict their EI at mealtimes, yet overconsume snack foods in between meals. In addition, as these snacks were often highly palatable, energy dense, high fat sweet snack foods, prolonged overconsumption is likely to lead to an accumulation of body mass.

When total macronutrient intake was assessed across the 24-hour DR assessment, it was revealed that HFA consumed more percentage fat compared to MFA and LFA, yet there were no differences in percentage consumption of protein or carbohydrates between groups. Finally, according to the LFPQ, analysis of food hedonics revealed that HFA displayed an enhanced explicit liking and implicit wanting for high fat sweet foods compared to MFA and LFA.

Taken together, the results of this chapter suggest that individuals in the highest tertile of YFAS ‘symptom count’ scores display an enhanced hedonic preference towards high and low fat sweet foods, as evidenced by greater cravings, consumption and LFPQ preferences towards these foods. In particular, the high consumption of HFSW snack foods in the HFA group is especially concerning due to the positive association between snack food intake and body weight. However, these preferences appear to be driven by both wanting and liking, which were found to be enhanced in individuals with high scores on the YFAS according to the LFPQ. Therefore, this preference towards high fat and sweet foods cannot be attributed to a hedonic dysregulation which might be expected if this were reflecting an ‘addiction’ towards food. It seems, therefore that a high score on the YFAS does not signify any dysfunctional relationship with food hedonics. These outcomes question what interpretation should be placed on the numerical value of a score on the YFAS.

8.2 Theoretical considerations

The research presented in this thesis represents a small section of a wider debate surrounding the validity and usefulness of FA. Some of the broader considerations with greater implications will be discussed here.

8.2.1 Usefulness of the term ‘food addiction’

One issue still to resolve is the extent to which so-called food addiction is a novel and useful label for susceptibility to well-documented and clinically-recognised forms of overeating (Davis, 2013a), such as binge eating disorder (Cassin & von Ranson, 2007). Furthermore, does FA add any further understanding to what is already known about eating difficulties? Vainik et al. (2015) recently suggested that many common eating-related traits can all be captured by a single factor, labelled “Uncontrolled Eating” (pg. 229), presented on a continuum indicating severity. This continuum model is in line with that proposed by Davis (2013a), and further highlights the extensive overlap between the hypothesised classification of food addiction and existing maladaptive eating behaviour phenotypes. However, it may be questioned whether such a continuum justifies the acceptance of so-called food addiction as a distinct clinical entity.

For FA to be considered a discrete addiction disorder, sufficiently different from existing clinical models of overeating (specifically binge eating), it would be reasonable to predict, as was hypothesised in Chapter 4, that the YFAS should identify unique traits of overconsumption indicative of an addiction which binge eating cannot. However, the results of this chapter revealed that individuals with high scores on the YFAS did not experience significant impairment to their quality of life, compromised psychological wellbeing, and a susceptibility towards addictive personality traits to a greater extent compared to those with high scores on the BES. At the present time, the concept of so-called food addiction at the individual level as a putative biological cause of overeating is controversial and lacks convincing support. The term is also not widely regarded as helpful by clinicians in advancing scientific understanding of eating disorders or as an explanation for obesity (Blundell & Finlayson, 2011).

With drug use, the number of people who go on from habitual drug taking to clinically defined substance dependence is very low (approximately 9%; Grant et al., 2004). Whilst the prevalence of so-called food addiction according to the YFAS is in a similar region, generally reaching 5-15% in the general population (for example; Brunault et al., 2014; Flint et al., 2014; Gearhardt et al., 2009b), the prevalence of worldwide overweight and obesity is far higher; predicted to have reached 46% in 2005 (Kelly, Yang, Chen, Reynolds, & He, 2008). The proposition, therefore, that a possible dependence on or addiction to particular foods could be responsible for elevated proportions of overweight and obesity in today's society is speculative and risks over-simplifying the situation by assigning the highly heterogeneous nature of overeating and weight gain to an ambiguous label. Instead, there appears to be a subset of the population who demonstrate a preference towards certain foods, such as energy dense (Chapter 5), high fat sweet foods and snack foods (Chapter 7). However, without identifying a specific substance which these potential 'food addicts' are dependent on, such behaviours cannot justifiably be interpreted as a substance 'addiction'.

One argument to be considered, given the limitations discussed here and throughout this thesis, is whether the notion of food addiction should be dispensed with entirely. This perspective is supported by the weak psychometric properties of the YFAS, as revealed in Chapter 3 and discussed below. If the concept of FA itself is largely based on the validity of the YFAS to measure and define it, the pitfalls of the YFAS are explicitly linked to the notion of FA itself. However, the danger pf completely rejecting the notion of phenotypes with addictive proclivities in relation to food means that an alternative model to explain those proclivities must be defined, given the number of people who perceive themselves as 'addicted' to food (e.g., Ruddock, Field & Hardman, 2017). Whilst evidence, including that reported in this thesis (Chapter 4, for example), might suggest that the proposed characteristics of FA are explainable by binge eating, there may yet be scope for an unknown substance related disorder that is not currently explicable by current models of disordered eating or overeating.

8.2.2 Identifying an 'addictive' substance

As discussed throughout this thesis, though many attempts have been made, no studies have conclusively identified a specific food or ingredient which individuals may convincingly become 'addicted' to. This does not help the case for the validity of FA.

In Chapter 5, for example, foods high in energy density were found to be rated as those most associated with ratings of problematic eating and addictive potential. However, such findings were typical of those individuals who did and did not meet a YFAS 'diagnosis' of FA. Consequently elevated YFAS scores do not appear to increase individual susceptibility towards perceiving foods as more problematic or as being more likely to have 'addictive potential'. Rather, high ED foods encourage (over-)consumption in many individuals, not limited to those with high YFAS scores.

In contrast, however, the results of Chapter 7 revealed differences in food preferences and consumption depending on YFAS scores. For example, the HFA group consumed a greater amount of high fat and sweet snack foods and reported a higher percentage intake of fat across the dietary recall assessment period. Furthermore, the LFPQ revealed an implicit preference towards wanting high fat sweet foods in the highest tertile of YFAS scores, whilst the HFA group reported the highest degree of craving for high fat sweet foods compared to the other groups. These problematic or addictive perceptions of high ED foods appear to manifest into maladaptive eating behaviours in those individuals with elevated YFAS scores. This problematic overconsumption of high ED and high fat foods in high YFAS scorers, coupled with the lower habitual physical activity and respiratory fitness revealed in the HFA group in Chapter 6, may dispose high YFAS-scoring individuals to overweight and obesity.

8.2.3 Proposed measurement of ‘food addiction’: the Yale Food Addiction Scale

Whilst YFAS-defined food addiction does seem to identify individuals with certain maladaptive eating behaviours (Eichen et al., 2013; Gearhardt et al., 2009b; Gearhardt, Yokum, et al., 2011; Mason et al., 2013), problems are inherent in the direct application of the DSM-IV-TR criteria for substance dependence as the basis of a psychometric tool for so-called food addiction. The diagnostic labels in the DSM are intended for trained and experienced clinicians rather than a checklist for self-diagnosis. Indeed, the diagnosis of any other scientifically validated addictive or eating disorder would not rely solely on a self-report questionnaire as justification for clinical diagnosis.

Furthermore, defining so-called food addiction under the same criteria as substance dependence and addictive behaviour is controversial because, unlike drugs, food and eating are essential for survival. There is disagreement over the equivalence of the symptoms of substance use disorders and the appropriateness of their application to so-called food addiction (Meule, von Rezori, et al., 2014; Ziauddeen et al., 2012b), especially given the abundance of foods in the diet that contain high proportions of the various candidate ‘addictive agents’ (e.g. fat and sugars).

As mentioned in Chapter 1, a further limitation of the YFAS is its design based on the now outdated DSM-IV symptom criteria. In 2013, the fifth edition of the DSM was published, reflecting major changes made to the previously titled ‘Substance-Related Disorders’ chapter (American Psychiatric Association, 2000). This category was re-named “Substance-Related and Addictive Disorders” and further subdivided into “Substance-Related Disorders” and

“Non-Substance-Related Disorders” (American Psychiatric Association, 2013). As previously discussed, despite some postulations (Gearhardt, Grilo, et al., 2011; Rizk & Treat, 2014; Schulte et al., 2015), no specific food or ingredient is yet to be conclusively characterised as an addictive agent in humans, whilst Gambling Disorder was the sole behavioural condition acknowledged under the Non-Substance-Related Disorders category. One explanation for the lack of recognition of food addiction under the DSM-5 can be attributed to the idea that the term generates confusion and conflicting accounts as it straddles both substance-related and non-substance-related disorders (Davis & Loxton, 2014). There are researchers who strongly implicate certain foods, such as highly “processed” foods (Schulte et al., 2015), as being more likely to trigger an ‘addiction’ in susceptible individuals via similar mechanisms as drugs of abuse (Gearhardt, Yokum, et al., 2011). However, contrasting views have suggested that it is the behaviour of eating which is potentially addictive (Davis & Loxton, 2014; Meule & Gearhardt, 2014b), generating debate over whether overeating, to the extent where it could be interpreted as reflecting an addiction, is best conceptualised as a maladaptive pattern of behaviours, or as a substance-related disorder.

In response to this, the term “eating addiction” (Hebebrand et al., 2014) has been proposed to acknowledge addiction to eating on a behavioural level. Furthermore, researchers from Liverpool University have recently developed a scale focussing on the behavioural aspects of overeating; the Addiction-Like Eating Behaviour Scale (AEBS; Ruddock, Christiansen, et al., 2017). This scale removes the reliance on the DSM criteria for substance-related disorders and focusses on identifying potential observable behaviours which could be indicative of addiction-like eating. As discussed in Chapter 3, the YFAS had a two-factor structure, representing “appetitive drive” and “dietary control”, which, though important aspects of overeating, do not necessarily represent any addictive behaviours. Furthermore, the terms “eating addiction” or “addiction-like eating” retain the semantically-charged term ‘addiction’ rather than a more neutral term which might be better suited to compulsive overeating behaviours (Finlayson, 2017). Applying the term ‘addiction’ to food is further impeded as the semantics of this label may no longer be appropriate. It seems unhelpful to persist with the term ‘food addiction’, especially as its supposed diagnosis arises from a questionnaire based on the criteria for substance *dependence*, not addiction. There is a risk that the term ‘food addiction’ may continue to be used by investigators for dramatic effect or to make a diagnosis appear toxic.

This is further discussed in a paper which cautions against ‘overpathologising’ behavioural addictions (Billieux, Schimmenti, Khazaal, Maurage, & Heeren, 2015). The authors warned that the progression of behavioural addiction research in recent years has led to nearly all daily activities becoming contenders for addiction, which may ultimately lead to a “dismissive appraisal of behavioural addiction research” (p. 119). This is similarly discussed in a recent paper by Finlayson (2017), who argued that FA represents a medicalisation of widely seen eating behaviours which presents negative implications for the perception of overeating and obesity. The overarching conclusions of both pieces of research emphasises that the neurobiological overlaps between substance and behavioural addictions are to be expected, given the potency of the natural reward mechanisms in the human brain. Furthermore, such simplistic conceptualisation of heterogeneous behaviours as addictions may lead to any number of the many features of sustained dysfunctional and compulsive behaviours being overlooked.

8.3 Limitations of the thesis

Though effort was made to ensure all studies were rigorously conducted, some limitations regarding the methodological processes employed within this thesis should be discussed. For example, as discussed in Chapter 2, the vast majority of studies including the YFAS rely on cross-sectional and self-report designs. Although such studies are useful to capture a ‘screenshot’ of human behaviour, it is important that the label of FA does not become attached to individuals already predisposed to overeating or overweight. Longitudinal studies are urgently required to examine the potential factors which may play a causal role in the development of behaviours which may be interpreted to represent a food addiction.

Further, Chapters 3 to 5 relied on self-report, questionnaire based data, recruited predominantly from a University-based population and with a disproportionately high number of female responders. Though this online design was necessary in order to achieve the appropriate power necessary to conduct the analyses in these chapters, and is inherent given the self-report nature of the YFAS, generalisation of these results beyond this sample should be conducted with caution. Future research would benefit from repeating these analyses with a more representative and diverse sample, or focussing on specific sub-groups of the population with adequate sample sizes and power.

The specific methodological techniques used are also not without their limits. For example, the factor analysis used in Chapter 3 presents issues regarding the reliability of this technique, particularly relating to sample size, whereby large samples are likely to lead to rejection of a model (Fabrigar et al., 1999). However, the range of goodness of fit indices considered in this chapter aim to provide a promising approach for assessing the fit of the model identified in the analyses.

The laboratory-based studies in Chapters 6 and 7 also presented limitations. The samples in both studies were restricted to females, thus the findings cannot be applied to males. Furthermore, research into the effects of laboratory-based settings suggests that this environment may encourage overconsumption in certain individuals (Raymond, Bartholome, Lee, Peterson, & Raatz, 2007; Wardle & Beales, 1987). However, the strong correlation in energy intake between the laboratory-based and dietary recall assessments in Chapter 7 suggests that the laboratory setting can be regarded as representative of total daily EI in females.

The dietary recall technique employed in Chapter 7 also presents methodological limitations. Self-report techniques are often subject to social desirability and researcher biases, particularly in those individuals who are conscious about their eating behaviour (Hebert et al., 2008; Maurer et al., 2006), leading to misreporting, notably under-reporting (Macdiarmid & Blundell, 1998). In this chapter, participants were blinded to the purpose of the second experimental test day to prevent any adapting of their habitual dietary intake, yet their recall of this intake may still have been misstated. These biases are also applicable to the self-reporting of physical activity included in Chapter 6 (Klesges et al., 2004). Whilst the use of accelerometers was employed to verify PA status, it is possible (though unlikely) that participants may have manipulated their habitual PA in order to adhere to desirable outcomes.

The use of the LFPQ in Chapter 7 is also not without its limitations. It has been proposed that, in the absence of actual food consumption, the measurement of liking or wanting relies on memory and previous experience of eating the food presented, rather than the actual sensory experience of eating it (E. Robinson, Blissett, & Higgs, 2013). This can lead to a misrepresentation of liking responses on the LFPQ. However, the ability to tailor the food images included on the LFPQ, removing any disliked foods, aims to overcome this limitation. Furthermore, as presented in Chapter 7, the LFPQ was able to differentiate high- and low-scoring YFAS individuals based on their implicit wanting of HFSW foods, demonstrating that this behavioural paradigm is sensitive to individual differences in food preferences and motivational state.

A further limitation of the thesis which must be considered is the differing thresholds used to define the YFAS groups across chapters. For example, Chapter 4 and Chapter 5 distinguish between an FA Group and Non-FA Group using the dichotomous YFAS ‘diagnosis’, whilst Chapter 6 and Chapter 7 use a tertile split of participants to define ‘low’, ‘medium’ and ‘high’ YFAS groups. Furthermore, given the differing samples used in the latter two chapters, the grouping of these tertiles were not consistent. In Chapter 6, a tertile split of YFAS scores in the sample used in Chapter 4 informed the grouping of participants. Conversely, the retrospective nature of the analysis in Chapter 7 meant that no such control could be applied to this sample and the tertiles differed in YFAS scores in comparison to Chapter 6. This notwithstanding, the ‘high’ YFAS groups in both samples were comparable, whereby both groups were defined by a YFAS score of 3 or above. It cannot be ignored that these different groups may have impacted the findings and comparison of results across chapters must be interpreted with caution. This limitation is evident across the literature of FA and may be attributed, in part, to the lack of characterisation of a ‘food addicted’ group and the number of ways to define this group, as advised by the authors of the YFAS (Gearhardt et al., 2009).

8.4 Future research

Despite the overarching conclusions of this thesis that FA should not be considered a valid clinical condition, whilst the prevalence of obesity worldwide continues to be a major burden, it is highly unlikely that the concept of FA will disappear. Therefore, it is pertinent that any future research adopts a non-biased approach and employs well-controlled methodology to critically examine the notion of FA.

In particular, the current research base is lacking longitudinal studies, qualitative assessments and more intensive food intake paradigms to attempt to decipher whether there is any genuine clinical symptomatology associated with high YFAS-scorers. Longitudinal studies are of particular importance given the chronic nature of both overeating disorders and substance abuse (Dennis & Scott, 2007; Ludwig & Friedman, 2014).

Moreover, it is unclear whether the increased prevalence of YFAS-defined FA in overweight or obese individuals is a potential cause or consequence of sustained overeating and weight gain. Such interrelationships can only be conclusively disentangled through longitudinal studies. Any future research on FA should ensure that the focus is not to advocate FA in its current state, but to develop a clear and precise definition or clinical syndrome for FA, if such exists.

Any future exploration into the concept of food addiction must be considered in the context of the wider research area. Factors such as whether the notion of FA, or its proposed diagnostic tool, the YFAS, should be completely rejected, given the significant empirical doubts about its utility, should be considered.

8.5 Conclusion

The dependency of the ‘food addiction hypothesis’ on animal and neurological research (Avena, 2010; Avena, Bocarsly, et al., 2012; Rogers & Smit, 2000; Ziauddeen et al., 2012b), as well as the circularity of the ‘diagnostic’ ability of the YFAS (C. G. Long et al., 2015), weakens the theoretical platform upon which the concept of ‘food addiction’ is based. The studies in this thesis provide little reliable evidence that any eating behaviours which are suggested to be comparable to an ‘addiction’ are evident in humans - and no evidence that the YFAS is able to identify or measure such behaviours. Much of the eating-related pathology which is presented by individuals with high scores on the

YFAS can be adequately explained by existing, clinically recognised disorders such as Binge Eating Disorder, or simply attributed to enhanced food preferences for highly palatable foods, without the need to implicate addiction as the justification for maladaptive eating behaviours or obesity (Corwin & Hayes, 2014; Finlayson, 2017).

At this stage, and consistent with good scientific practice, the existence of so-called food addiction and its relationship with other psychological processes, should be regarded as inconclusive until such time as the evidence base becomes stronger. Food addiction is academically interesting, yet the perspective that a simple questionnaire with weak psychometric properties can diagnose a legitimate clinical condition is empirically unrealistic.

Appendices

Appendix A

Table of results from the Systematic Research Review (Chapter 2)

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Boggiano et al. (2014) Appetite	249 weight-loss seeking patients and 247 undergraduate students	PEMS, YFAS, BES, BMI	Mean YFAS symptom count of 3.1 (SD 1.7)	Mean YFAS symptom count of 1.9 (SD 1.3)		The YFAS correlated significantly with BES scores in both the overweight and control samples			Large sample size and control group but predominantly females and controls not well age or gender matched Only self-report measures
Brunault, Ballon, Gaillard, Reveillere, and Courtois (2014) Canadian Journal of Psychiatry	553 French participants	YFAS (translated to French), BES, BITE, BMI		8.7% met FA diagnosis Mean YFAS symptom count was 1.9 (SD 1.4) Median number of food addiction criteria endorsed was 1		YFAS symptom count was significantly correlated with BES total and BITE symptom scores. Dichotomous FA diagnosis was significantly correlated with higher BES and BITE scores			Large sample size but did not report gender Only self-report measures

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Burgess, Kuran, Lokken, Morse, and Boggiano (2014) Appetite	150 college undergraduates; 106 female, 44 male	PEMS, BES, YFAS SPSRQ				YFAS scores did contribute to some of the variance in BMI but failed to do so once BES scores were controlled		Significant associations between the PEMS subscales (social, coping, enhancement and conformity) and YFAS scores	Predominantly female sample with age and education biases Laboratory measured BMI but self-reported questionnaires
Burmeister, Hinman, Koball, Hoffmann, and Carels (2013) Appetite	51 overweight / obese patients seeking WLT	YFAS, CES-D, BES, DEBQ	19.6% of sample met FA criteria: 3 males, 8 females (YFAS symptom count) Mean number of YFAS symptoms was 3.13 (SD 1.74)			More YFAS symptoms was associated with higher self-reports of binge eating behaviours	Individuals with higher YFAS scores lost a smaller percentage of body weight after the 7 week WLT intervention	Those who reported more YFAS symptoms also indicated experiencing greater depression	Small sample size, predominantly female Weight loss measured after only 7 weeks, before any WL manipulation had begun

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Clark and Saules (2013) Eating Behaviors	67 post-WLS patients, 62% female	YFAS, BES, MAST-AD, ASSIST	53.7% met criteria for FA			Significant relationship between YFAS symptom count and emotional eating and binge eating Significant relationship between dichotomous YFAS diagnosis and emotional eating, binge eating and symptoms of eating disorders	Those meeting FA criteria has poorer total weight loss outcomes - 32% vs. 27% (not statistically significant)	Those meeting FA diagnosis were more likely to admit post-WLS problematic substance use (not statistically significant)	Small sample, predominantly female All measures (inc. BMI) were self-reported Retrospective reporting of pre-WLS answers
Davis et al. (2011) Appetite	72 obese adult women (N = 49) and men (N = 23)	YFAS, EDE-Q, BDI, WURS-25, BIS, DGT, DDT, EPQ, BEQ, PFS, DEBQ, FCQ, EBPQ	18 adults met FA diagnosis (13 female, 5 male) 25%			Significant correlation between FA and BED diagnosis Food addicts reported more binge, hedonic and emotional eating		Food addicts had a significantly higher prevalence of severe depression and were more likely to meet the criteria for childhood ADHD	Small sample, more than 2x more women than men Two computerised behavioural tests (DGT and DDT)

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Davis et al. (2013) Physiology and Behavior	120 overeating/ overweight women (N=82) and men (N=38)	YFAS, MLGP score, PFS, BEQ, DEBQ, FCQ, EBPQ	21 participants met food addiction diagnosis (17.5%; 16 females, 5 males)			MLGP score higher in FA group than controls The food addiction group had significantly higher scores on all five measures of eating behaviour			Over 2X more females than males Thorough biological measurement of MLGP and BMI in the lab but other measures were self-report
Davis, Levitan, Kaplan, Kennedy, and Carter (2014) Frontiers in Psychology	136 overweight/ obese women (N=92) and men (N=44)	YFAS, FCQ, appetite ratings, snack food consumption	23 met FA diagnosis (16.9%)			Food addicts reported higher food cravings and appetite ratings The FA group showed no suppression of appetite when administered methylphenidate compared to placebo			Female-biased sample Measured actual food consumption. Found significant differences in responses to snack food in FA compared to non-FA groups
Davis and Loxton (2014) Nutrients	145 adult women (N=100) and men (N=45)	Genotyping (DNA extraction), YFAS, FPQ, PFS, FCQ	25 met food addiction diagnosis (17.2%)			YFAS symptom score was positively associated with hedonic responsiveness which mediated the relationship between A118G marker and FA			Female-biased sample DNA extraction allows comparison of biological markers

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Eichen, Lent, Goldbacher, and Foster (2013) Appetite	178 overweight/ obese WLT seeking females (N=133) and males (N=45)	YFAS, BDI, BMI	15.2% met FA diagnosis Average symptom count in full sample was 2.57 (SD 1.67)					Food addicts (dichotomous and symptom count) had significantly higher BDI scores	Female-biased sample Sample seeking WLT - motivated to report more severe symptoms to qualify for treatment
Flint et al. (2014) American Journal of Clinical Nutrition	134,175 female NHS nurses aged 45-88 years	YFAS, moderated YFAS, demographic factors		5.8% met a full food addiction diagnosis The prevalence of FA measured by the mYFAS was 8.4%		Women with food addiction were more likely to be overweight		Depression was positively correlated with FA	Female-only sample Used moderated version of YFAS Measures of covariates were obtained from retrospective data
Gearhardt, Corbin, and Brownell (2009) Appetite	233 undergraduate females (64.2%) and males (35.8%)	Development of the YFAS using BES, BIS/BAS, ETM, EES, RAPI, DDQ		11.4% met FA diagnosis Median symptom count was 1		YFAS symptom count was a significant predictor of binge eating scores after controlling for EAT and EES, explaining 14.8% of unique variance In the same way, YFAS diagnostic count explained 5.8% of unique variance		A small but significant correlation was found between YFAS scores and problematic alcohol use and BIS but not BAS	Large sample but biased towards undergraduate students All self-report measures

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Gearhardt et al. (2011) Archives of General Psychiatry	39 females Excluded those with eating disorders and Axis I disorders	BMI, YFAS, DEBQ, fMRI Participants split into high FA group with 3 or more symptoms (N=15) or low FA with 1 or fewer symptoms (N=11)		High FA group endorsed 3.6 symptoms on average (SD 0.63) Low FA group endorsed 1 symptom		YFAS scores correlated with emotional eating and external eating subscales of the DEBQ			Small, female only sample Measured brain reactivity using fMRI in response to anticipated and actual palatable food consumption (milkshake)
Gearhardt et al. (2012) International Journal of Eating Disorders	81 obese women (70.1%) and men treatment seeking BED patients	EDE, YFAS, BDI, DERS, RSE, height and weight	56.8% met diagnostic FA threshold Mean number of FA symptoms met was 4.56 (SD 1.9) Of those not meeting FA diagnosis (N=35), 57.1% endorsed 3 or more symptoms but did not meet the threshold for clinical impairment			YFAS scores were significantly positively correlated with frequency of binge eating episodes and with EDE eating, shape and weight concern and global EDE score		FA was not associated with anxiety, alcohol or drug use but was significantly associated with a greater likelihood of mood disorder diagnoses, negative affect emotional dysregulation and lower self-esteem	Female-biased, small sample All self-report measures

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Gearhardt, White, Masheb, and Grilo (2013) Comprehensive Psychiatry	96 obese female (N=72) and male (N=24) patients with BED	EDE, YFAS, BDI, DERS, QWERP-R, height and weight	41.5% met diagnostic FA threshold Mean number of FA symptoms met was 4.33 (SD 1.81)			YFAS scores were significantly positively correlated with frequency of binge eating episodes and with EDE eating, shape and weight concern and global EDE score YFAS scores were associated with an earlier age of first being overweight and age of dieting onset		YFAS diagnosis was not associated with mood, anxiety, alcohol or drug use disorders YFAS symptom count was significantly correlated with higher negative affect, emotion dysregulation and lower self-esteem	Female-biased sample All self-report measures
Gearhardt, Roberto, Seamans, Corbin, and Brownell (2013) Eating Behaviors	75 children, 42.7% female, average age 8.32 years	Development of YFAS-C using BMI, CEBQ			7.2% met FA diagnostic threshold	Elevated scores on the YFAS-C were related to higher BMI and higher levels of emotional overeating			Used moderated version of the YFAS for children – limited generalisation to adult samples Near-even male-female gender split Low prevalence of FA means limited assessment of FA in children

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Gearhardt, Rizk, and Treat (2014) Appetite	89 overweight and obese women	EDE-Q, YFAS, BMI, food stimuli, hunger ratings	Mean number of YFAS symptoms endorsed was 3.06			YFAS symptom count was a moderate predictor of cravings for low processed and fat based foods Those who reported more YFAS symptoms craved more than their peers			Female only sample Craving and liking were in response to photos of food only, not actual food
Gearhardt, Boswell, and White (2014) Eating Behaviors	815 community female (N=717) and male (N= 97) participants	EDE-Q, QEWP-R, YFAS		25.7% (N=207) met the diagnostic threshold for FA Mean number of symptoms endorsed was 3.05 (SD 2)		FA was associated with higher current and lifetime BMI, earlier age of first dieting, time spent dieting and weight cycling FA was associated with binge eating behaviours, dietary restraint, shape, weight and eating concern			Female-biased sample but a large community population Self-report measures only Included comparison of eating pathology across FA/BN groups

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Granero et al. (2014) European Eating Disorders Review	207 female participants 125 eating disorder patients 82 healthy controls	EDI-2, SCL-90-R, YFAS Development of YFAS-S		2.4% of healthy control sample met FA diagnostic threshold Mean symptom count was 1.7	72.8% of eating disorder patients met FA diagnostic threshold 60% of AN,81.5% of BN, 76.9% of BED and 72.2% of EDNOS Mean symptom count was 4.7	BMI and number of binges per week positively correlated with the YFAS-S score			Female only sample Control group was not age or BMI matched Uneven split of ED types Used Spanish YFAS
Imperatori et al. (2014) Comprehensive Psychiatry	112 overweight/ obese females (N=80) and males (N=32) seeking low-energy diet therapy	YFAS, BES, SCL-90-R	33.9% (N=38) met the FA diagnostic threshold			Among patients with FA, 28.9% also satisfied criteria for clinical level binge eating, compared to only 4.1% of those without FA		The relationship between FA and psychopathology was entirely mediated by binge eating severity	Female-biased sample Used Italian YFAS WLT seeking sample – motivated to report severe eating psychopathology
Innamorati et al. (2015) Eating and Weight Disorders	300 overweight/ obese females (N=246) and males (N=54) 300 healthy controls (231 females, 69 males)	YFAS, BES				YFAS score was significantly correlated with BES score Both the YFAS-16 score and BES were significantly associated with BMI, accounting for 25% of the variance in the data			Female-biased sample Control group who did not differ in mean age or gender Used Italian YFAS

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Karlsson et al. (2015) The Journal of Neuroscience	13 morbidly obese women 14 healthy non-obese matched controls	YFAS and other food and personality questionnaire PET scanning measured D2 and mu-opioid receptor availability	Mean YFAS score of 18 (SD 11)	Mean YFAS score of 7.86 (SD 5.95)		Morbidly obese participants scored significantly higher on the YFAS compared to controls YFAS scores were negatively associated with MOR availability in the dorsal caudate			Female only sample PET scanning allowed comparison of MOR and D2R availability
Lent, Eichen, Goldbacher, Wadden, and Foster (2014) Obesity	178 overweight or obese females (N=133) and males (N=45) seeking WLT	YFAS, height and weight, demographic information	15.2% (N=27) met FA diagnosis at baseline FA symptom count at baseline was 2.6 (SD 1.7)				No effect of dichotomous or symptom count FA on weight loss after controlling for sex and baseline weight Variance in weight change was not significantly different by baseline FA status		Adapted the YFAS to only measure FA in the past month Studied prospective weight loss and its relationship with FA over 5-6month treatment course Motivated WLT seeking sample

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Mason, Flint, Field, Austin, and Rich-Edwards (2013) Obesity	57,321 female registered nurses in the Nurse's Health Study II	Measures of physical or sexual abuse in childhood or adolescence, mYFAS		8.2% met FA diagnosis		Women meeting FA diagnosis were 6units of BMI heavier than those not meeting FA criteria Almost 2/3 of women with FA were obese compared to ¼ without FA		Found dose-response associations between physical and sexual abuse severity in childhood or adolescence and the likelihood of adult food addiction	Female only sample Used modified (9 item) YFAS limiting generalisability of FA prevalence and covariates Abuse questionnaires were retrospective
Mason et al. (2014) JAMA Psychiatry	49,408 female registered nurses in the Nurse's Health Study II	mYFAS, PTSD questionnaire assessing trauma exposure and PTSD symptoms		8% met FA diagnosis				Dose-response association between the number of lifetime PTSD symptoms and prevalence of food addiction in middle adulthood. This was further elevated when PTSD symptoms occurred earlier in life	Female only sample Used modified (9 item) YFAS limiting generalisability of FA prevalence and covariates PTSD was measured retrospectively

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Meule, Skirde, Freund, Vogele, and Kubler (2012) Appetite	56 healthy weight females (N=47) and males (N=9) High cravers (N=28) and low cravers (N=28)	FCQ, EDE-Q, YFAS, photographic food stimuli, n-back response task		FA symptom count mean was1.11 in the low cravers group (SD .50) and 2.54 in the high cravers group (SD 1.35)		High cravers reported more eating related psychopathology as measured by the YFAS			Small sample size, predominantly female Measured behavioural responses to photo stimuli of high calorie savoury and sweet food
Meule, Lutz, Vogele, and Kubler (2012) Appetite	617 participants (75.8% female)	FCQ-trait, YFAS, RS-CD, PSRS, FC12, RC16, EDEQ, MaCS, BIS, PANAS				Food addiction symptoms were positively related to FCQ-T scores			Female-biased sample Focused on the psychometrics of German YFAS
Meule, Lutz, Vogele, and Kubler (2012) Eating Behaviors	50 normal weight female students	YFAS, CES-D, BIS,-15, FCQ (state version), XY response task		Mean FA symptom count was .83 (SD .38) in low FA and 2.65 (SD .75) in high FA group		FA symptoms positively correlated with BMI		Food addiction symptoms were positively correlated with depressive symptoms	Female sample Split sample into high and low FA groups – did not compare FA to no FA Behavioural task
Meule and Kubler (2012) Eating Behaviors	617 participants (75.8% female)	FCQ (trait version), YFAS, BMI		7.8% met FA diagnosis (N=48)		Individuals with a FA diagnosis scored higher on the global FCQ-T and all subscales except positive reinforcement)			Female-biased sample Minimal covariate analysis

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Meule, Heckel, and Kubler (2012) European Eating Disorders Reviews	96 overweight or obese females (N=63) and males (N=33) seeking WLS	YFAS	41.70% met FA diagnosis (N=40) Mean YFAS symptom count was 3.42 (SD1.74)						Female-biased, motivated sample Assessed factor structure of German YFAS, did not report covariates
Meule, Freund, Skirde, Vogele, and Kubler (2012) Applied Psychophysiology and biofeedback	56 healthy weight females (N=47) and males (N=9) High cravers (N=28) and low cravers (N=28)	FCQ-trait, EDEQ, YFAS, PSRS; ERQ, locus of control, HRV				More FA symptoms were reported in the high craving control group compared to the high craving biofeedback group and low craving group			Female-biased sample Analysed high cravers vs low cravers, not FA vs no-FA Identified HRV as a potential treatment for FA
Meule, Heckel, Jurowich, Vogele, and Kubler (2014) Clinical Obesity	94 overweight or obese females (N=63) and males (N=33) seeking WLS	YFAS, FCQ, EDEQ, BIS, AUDIT, CES-D	40.4% met FA diagnosis (N=38) Mean YFAS symptom count was 3.39 (SD1.75)			FA group had higher FCQ-T scores and EDE-Q subscales eating, weight and shape concern scores and total EDE-Q FA group reported more binge days		FA group scored higher on the BIS attentional impulsivity subscale and had higher CES-D scores FA had lower AUDIT scores	Female-biased, motivated sample Self-report measures and no follow up after WLS

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Meule, Lutz, Vogele, and Kubler (2014) Eating Behaviors	50 normal weight female students	YFAS, BMI, BIS, FCQ-S, SST		Mean YFAS symptom count was 1.56 (SD 1.05)		YFAS symptom count was positively correlated with BMI YFAS symptoms were not associated with FCQ-S scores		YFAS scores were not correlated with BIS scores or reaction task performance	Female only sample Included a behavioural food impulsivity measure
Meule, von Rezori, and Blechert (2014) European Eating Disorders Reviews	109 female participants with either current BN (N=26), history of BN (N=20) or control group (N=63)	YFAS, EDE-Q, DEBQ, symptom inventories, CES-D		30% of remitted BN patients (N=6) received FA diagnosis Their mean FA symptom count was 3.95 (SD1.79) None of the control group met FA diagnosis (mean symptom count .86 (SD.90)	All current BN patients (N=26) received an FA diagnosis Their mean FA symptom count was 6.27 (SD1.04)	FA group had higher eating disorder psychopathology YFAS symptom count was positively correlated with all measures of eating disorders		FA group had higher general psychopathology YFAS symptom count was positively correlated with general psychopathology	Female only sample Self-report measures only Analysed FA specifically in relation to BN and not BED

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Meule, Hermann, and Kubler (2015) European Eating Disorders Reviews	50 overweight or obese adolescent females (N=31) and males (N=19) seeking WLT	YFAS, FCQ-T, EDE-Q, BIS, CES-D	38% (N=19) received an FA diagnosis Mean FA symptom count was 3.38 (SD 2.11)			Food addicts had higher eating, weight and shape concerns, reported more days binge eating and food craving episodes		Food addicts had more symptoms of depression and scored higher on attentional and motor impulsivity	Motivated sample to qualify for WLT Small sample, predominantly female Patients were mid-WLT but the study did not follow up post WLT
Murphy, Stojeck, and MacKillop (2014) Appetite	233 students Females N=179 Males N=54	UPPS-P, YFAS		24% met FA criteria Mean YFAS symptom count was 1.80 (SD1.39)		FA was significantly positively correlated with BMI		FA was correlated with increased scores on all subscales of the UPPS-P except sensation seeking	Female biased sample Only measured FA and impulsiveness, both by self-report
Pedram et al. (2013) PLoS ONE	652 healthy Canadian females (N=415) and males (N=237)	Body composition, YFAS, macronutrient intake	Prevalence of 7.7% in overweight or obese participants	5.4% met FA diagnosis (6.7% in women, 3.0% in men)		FA prevalence significantly increased with increasing obesity status regardless of how adiposity was defined			Female biased sample Measured body composition (not just BMI) and retrospective food intake and exercise in FA and non-FA groups Low prevalence of FA restrains comparison between FA and non-FA groups

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Pepino, Stein, Eagon, and Klein (2014) Obesity	44 obese females (N=39) and males (N=5) undergoing WLS	YFAS, DEBQ, FCI	FA was identified in 32% of subjects (N=14) before surgery WLS resulted in a remission of FA in 13 of the 14 FA subjects (93%)			Surgery induced weight loss decreased food cravings in both FA and non-FA groups, but the decrease was greater in the FA group			Female biased, motivated sample Measured patients at baseline and 9 month follow up Longitudinal effects of FA on weight loss
Reslan, Saules, Greenwald, and Schuh (2014) Substance Use and Misuse	141 post-WLS females (N=112) and males (N=29), at least 24 months post WLS	Preoperative and current BMI, MAST-AD, ASSIST, YFAS, NEQ, PFS, TFEQ, QEWP-R, EDE, EES	36% (N=53) met criteria for pre-surgical food addiction			Significant correlation between YFAS symptom count and NEQ		Post-RYGB patients who also endorsed substance use criteria had significantly higher scores on YFAS	Female biased, motivated sample Pre-surgical measurements were all retrospective No follow-up

Authors	Sample	Measures	Prevalence			Correlates			Critical analysis
			Obese or overweight	General population	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Schulte, Avena, and Gearhardt (2015) PLoS ONE	Study 1: 120 students (92 female, 28 male) Study 2: 384 females (N=156) and males (N=228)	Study 1: YFAS, forced choice task Study 2: YFAS, food ratings		Study 1: Mean FA symptom count 1.85 (SD1.33) Study 2: Mean FA symptom count 2.38 (SD 1.73)		YFAS symptom count was associated with BMI Level of processing led to the most problematic, addictive-like eating behaviours Level of processing was a positive predictor of food ratings of problematic addictive eating behaviour			Female biased sample Only photos of foods were used, no real food intake or anticipated intake was measured but forced choice task measured behavioural responses to foods

Legend: YFAS = Yale Food Addiction Scale; FA = Food Addiction; PEMS = Palatable Eating Motives Scale; BES = Binge Eating Scale; BMI = Body Mass Index; BITE = Bulimic Investigatory Test, Edinburgh; SPSRQ = Sensitivity to Punishment Sensitivity to Reward Questionnaire; WLT/S = Weight Loss Treatment/Surgery; CES-D = Centre for Epidemiological Studies Depression Scale; DEBQ = Dutch Eating Behaviour Questionnaire; MAST-AD = Michigan Assessment Screening Test for Alcohol and Drugs; ASSIST = Alcohol, Smoking and Substance Involvement Screening Test; EDE-Q = Eating Disorder Examination; BDI = Beck Depression Inventory; WURS-25 = Wender Utah ADHD Rating Scale; BED; Binge Eating Disorder; DGT = Delay of Gratification Task; DDT = Delay Discounting Task; EPQ = Eysenck Personality Questionnaire; MLGP = Multilocus Genetic Profile; PFS = Power of Food Scale; BEQ = Binge Eating Questionnaire; FCQ = Food Craving Questionnaire; EBPQ = Eating Behaviours Patterns Questionnaire; FPQ = Food Preference Questionnaire; BIS = Behavioural Inhibition Scale; BAS = Behavioural Approach Scale; ETM = Eating Troubles Module; EES = Emotional Eating Scale; RAPI = Rutgers Alcohol Problem Index; DDQ = Daily Drinking Questionnaire; fMRI = Functional Magnetic Resonance Imaging; DERS = Difficulties in Emotion Regulation Scale; RSE = Rosenberg Self-Esteem Scale; QWERP-R = Questionnaire on Eating and Weight Problems – Revised; YFAS-C = YFAS for children; CEBQ = Children's Eating Behaviour Questionnaire; EDI-2 = Eating Disorder Inventory 2; SCL-90-R = Symptom Checklist Revised; YFAS-S = Spanish YFAS; PSRS = Perceived Self-Regulatory Success in Dieting Scale; ERQ = Emotion Regulation Questionnaire; HRV = Heart Rate Variability; PTSD = Post-Traumatic Stress Disorder; RS-CD = Restraint Scale-Subscale Concern for Dieting; PSRS = Perceived Self-Regulatory Success in Dieting; FC12 = Flexible Control of Eating Behaviour; RC-16 = Rigid Control of Eating Behaviour; MaCS = Mannheimer Craving Scale; PANAS = Positive and Negative Affect Schedule; AUDIT = Alcohol Use Disorders Identification Test; BN = Bulimia Nervosa; SST = Stop Signal Task; UPPS-P = Impulsive Behaviour Scale; FCI = Food Craving Inventory; NEQ = Night Eating Scale; TFEQ = Three Factor Eating Questionnaire; QEWP-R = Questionnaire on Eating and Weight Patterns – Revised.

Appendix B

Table of results from the amendment to the Systematic Research Review (Chapter 2)

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Ahmed, Sayed, Mostafa, Abdelaziz (2016)	400 adolescents (51% female)	YFAS-C translated into Arabic, CDI, SCARED				12% met YFAS diagnosis (N=48)			81.2% had comorbid FA, anxiety and depression. FA scores correlated with anxiety and depression.	Large sample size of adolescents Correlations between FA and anxiety/ depression are unsurprising given the semantics of the YFAS
Ahmed & Sayed (2016)	801 adolescents (aged 11-18; 53.6% female)	YFAS-C translated into Arabic, measured BMI				15.7% met YFAS diagnosis		YFAS symptoms differed across BMI weight categories, but FA 'diagnosis' did not		FA group were significantly older
Ahmed, Sayed, Alshahat & Elzaziz (2017)	401 adolescents (aged 11-18; 55.1% female)	Measured BMI, BES, YFAS-C translated into Arabic				20.2% met YFAS criteria (N=81)	Significant positive relationships between YFAS symptoms and binge eating			Those with clinical BE had the highest proportions of all symptoms of FA

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Albayrak et al. (2017)	242 adolescent (aged 13-18) Psychiatric inpatients, 65.3% female	German YFAS, TFEQ, Psychiatric disorders according to DSM-IV, measured BMI			16.5% met YFAS criteria (N=40), mean 'symptom count' of 2.39 (±1.60)		42.5% of FA patients met criteria for an ED. YFAS score significantly higher in ED patients			First study to report YFAS in psychiatric inpatient adolescents. Non-linear relationship between YFAS score and BMI
Baldofski et al. (2015)	233 pre-operative bariatric surgery patients (69% female)	DSM-5 criteria for BED and NES, EDE, EDE-Q, DEBQ (emotional eating subscale), YFAS (German translations), measured BMI					BED and NES patients did not differ in YFAS symptoms, but both groups had significantly higher scores compared to non-ED group			Increased YFAS scores in obese patients with BED and NES. No information of prevalence diagnostic YFAS score
Baldofski et al. (2016)	240 pre-operative bariatric surgery patients, 68.75% female	WBIS, DERS, EDE-Q, YFAS, DEBQ, EAH (German translations), measured BMI					Correlations between YFAS, WBI and emotional eating. Emotion dysregulation partially mediated the relationship between WBI and FA			Concluded that higher WBI may contribute directly and indirectly (through impaired emotion regulation) to higher YFAS score

Authors	Sample	Measures	Prevalence: Obese or overweight	Prevalence: General population	Prevalence: Eating or Psychiatric disorders	Prevalence: Children/ adolescents	Correlates: Problematic eating	Correlates: Weight loss/ BMI	Correlates: Psychological wellbeing	Critical analysis
Bankoff et al. (2016)	642 male veterans	EDDS, YFAS, sexual orientation		1.9% met YFAS criteria, mean YFAS symptom count was 1.29 (±1.75)			Sexual minority orientation and higher BMI were significantly associated with higher YFAS scores			Low FA prevalence. Sexual minority males more likely to experience problematic eating behaviours including FA
Berenson et al. (2015)	1067 Low-income, reproductive-aged adult women	Measured BMI, self-report smoking and alcohol use and physical activity, BDI-FS, YFAS		2.8% met YFAS criteria (N=30)					Degree of depressive symptoms differed according to YFAS ‘diagnosis’	Low FA prevalence. Women with FA more likely to have higher levels of depression

Authors	Sample	Measures	Prevalence: Obese or overweight	Prevalence: General population	Prevalence: Eating or Psychiatric disorders	Prevalence: Children/ adolescents	Correlates: Problematic eating	Correlates: Weight loss/ BMI	Correlates: Psychological wellbeing	Critical analysis
Brunault et al. (2016)	188 obese pre-operative bariatric surgery patient, 84% female	BMI, YFAS (French translation), QOLOD, shortened BDI, BES	16.5% met YFAS criteria						FA group were more likely to be single and had significantly lower quality of life, greater levels of depression and higher binge eating.	Prevalence higher than general population, yet previous studies in obese samples have reported prevalence of >50%. Significantly higher binge eating in FA group, yet 36% of FA patients had no significant binge eating
Burrows et al. (2017)	150 parents/ caregivers and their 150 children	mYFAS, YFAS-C, CFQ				12% of parents (N=18) and 22.7% of children (N=34) met YFAS criteria	Parents of children meeting FA criteria reported significantly higher levels of restriction and pressure to eat feeding practices	FA was associated with BMI in children, with mean BMI more than 3 times greater in FA compared to non-FA group		Insight into associations between children and parent feeing habits. Parents feeding practices possible cause of problematic eating in children

Authors	Sample	Measures	Prevalence: Obese or overweight	Prevalence: General population	Prevalence: Eating or Psychiatric disorders	Prevalence: Children/ adolescents	Correlates: Problematic eating	Correlates: Weight loss/ BMI	Correlates: Psychological wellbeing	Critical analysis
Canan et al. (2017)	100 treatment-seeking males with heroin use disorder (HUD) and 100 male controls	DSM criteria for eating disorders, API, YFAS, BIS (Turkish translations)			28% of patients with HUD and 12% of controls met YFAS criteria for FA Patients with FA were sig. more likely to meet BED criteria than those without FA		39.3% of HUD patients with FA also satisfied criteria for BED		Current FA was associated with having a history of suicide attempts in HUD patients	Well-matched sample. Possible evidence for addiction transfer, applying addictive behaviours from heroin to food
Ceccarini, Manzoni, Castelnuovo & Molinari (2015)	88 adult obese inpatients undergoing WLT (N=63 female)	BMI (self-report but cross-checked with objective measures), BES, clinical interview for BED, YFAS-16 (Italian), BIS-11, DERS	34.1% met YFAS criteria for FA (N=30)				Sig. differences between FA and Non-FA in BES. Correlations between YFAS ‘symptom count’ and BES		Differences between FA and Non-FA DERS total score and DERS impulse subscale. Correlations between YFAS ‘symptom count’ and DERS and BIS	Low prevalence of FA in obese sample compared to previous research

Authors	Sample	Measures	Prevalence: Obese or overweight	Prevalence: General population	Prevalence: Eating or Psychiatric disorders	Prevalence: Children/ adolescents	Correlates: Problematic eating	Correlates: Weight loss/ BMI	Correlates: Psychological wellbeing	Critical analysis
Chao et al. (2017)	178 obese subjects seeking (non-surgery) weight loss treatment, 88.2% female	Weight and Lifestyle Inventory, QEWP, YFAS, Medical Outcomes Study (SF-36), IWQOL-Lite, PHQ-9, measured BMI	6.7% met YFAS criteria for FA (N=12)				6 ppts diagnosed with BED and 50% of these (N=3) also met FA criteria		Ppts who met criteria for FA had lower QOL according to HRQOL, SF-36 and IWQOL and more depressive symptoms	Very low prevalence of FA and BED in obese sample. YFAS accounted for sig. additional variance in QOL above BED diagnosis
Cornelis et al. (2016)	9314 females from Nurses' Health Study	mYFAS, self-report BMI, Genotyping		Prevalence of FA in 3% (N=100), 2.6% (N=70), 1.9% (N=47) and 8.7% (N-70) in each of the NHS cohorts			Genes linked to addiction traits were not associated with mYFAS			Large sample size yet, no conclusive evidence of shared genetic underpinnings of FA and drug addiction
De Ridder et al. (2016)	20 healthy normal-weight adults, 38 obese and 14 alcohol addicts	Anthropometrics and body composition, EEG analysis, blood sampling, questionnaires (YFAS, BIS/BAS, DEBQ, BES, mindful eating questionnaire food awareness subscale)	N=3 met the YFAS criteria for FA in the obese group						FA shares common neural brain activity with alcohol addiction. Obese FA and obese non-FA show opposite activity in the anterior cingulate gyrus.	High FA group and alcoholics group share common pathological brain activity, not present in the low YFAS group

Authors	Sample	Measures	Prevalence: Obese or overweight	Prevalence: General population	Prevalence: Eating or Psychiatric disorders	Prevalence: Children/ adolescents	Correlates: Problematic eating	Correlates: Weight loss/ BMI	Correlates: Psychological wellbeing	Critical analysis
Dietrich, de Wit & Horstmann (2016)	105 (N=60 F) normal weight, overweight and obese adults	UPPS Impulsive Behavior Scale, YFAS, IQ (Wiener Matritzen-Test), visual short-term memory (Visual Paired Associates Test), instrumental learning paradigm	N=7 met YFAS criteria for FA. Obese group had significantly more YFAS symptoms than normal weight or overweight groups							Very few participants displayed YFAS symptoms and 7 met full criteria. Therefore no analyses could be conducted on the YFAS
Epstein et al. (2016)	N=30 full responses on the YFAS. Adult restrained eaters	CRF1 antagonist pexacerfont or placebo administration (RCT), YFAS every evening (with video confirmation of completion), bogus taste test					YFAS ratings were lower with pexacerfont than placebo			Unusual effects of pexacerfont found as effects found on day 1 of administration when plasma levels would be too low to detect behavioural effect

Authors	Sample	Measures	Prevalence: Obese or overweight	Prevalence: General population	Prevalence: Eating or Psychiatric disorders	Prevalence: Children/ adolescents	Correlates: Problematic eating	Correlates: Weight loss/ BMI	Correlates: Psychological wellbeing	Critical analysis
Franken, Nijs, Toes & van der Veen (2016)	N=61 University students (N=30 who met the YFAS criteria for FA, N=31 controls)	YFAS, Eriksen flanker task, EEG		YFAS used to group participants into FA or control groups					FA group made more mistakes on the flanker task than controls. Significant correlation between YFAS symptoms and mistakes on flanker task	Small sample size. High YFAS scores are associated with impaired performance monitoring. FA may be characterized by impaired cognitive control.
Frayn, Sears & von Ranson (2016)	N=61 adults (N=31 who met the YFAS criteria for FA, N=35 controls)	YFAS, EDE-Q, EES, self-report BMI, hunger and satiety VAS, mood induction, eye-tracking, mood measurement					FA group had significantly higher scores on all EDE-Q and EES subscales compared to controls		FA group showed increased attention to unhealthy images following the sad mood induction and decreased attention to healthy images	Small sample size. Possible implications regarding cognitive factors underlying FA
Goluza et al. (2017)	N=93 outpatients (N=25 F) possessing a diagnosis of schizophrenia	YFAS			26.9% met YFAS criteria for FA (N=25)					Prevalence of FA in patients with schizophrenia higher than general populations but not as high as those with eating disorders

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Hilker et al. (2016)	N=66 female adult bulimia nervosa patients (N=55 completers)	YFAS, SCL-90-R, EDI-2, psycho-educational intervention			At baseline, 90.6% of the sample met YFAS criteria for FA, mean YFAS symptom count 6.1		Significant reduction in FA diagnoses from pre to post intervention (90.6 to 72.9%)			Large proportion of FA in BN patients raises the question over whether they are differentiable
Hsu et al. (2017)	N=20 obese 'sweet food addicts' (according to YFAS). N=20 controls (non-obese, non-FA). All females	YFAS, BIS-11, TFEQ, Go/No-Go task, fMRI, BMI, body fat %					Obese FA group had higher impulsivity, uncontrolled eating, and emotional eating and lower cognitive restraint than the control group.	Obese FA group had higher BMI and BF%	Association between uncontrolled eating and impaired inhibitory control in OFA group only. Lower brain activation when processing response inhibition in OFA	Small sample size recruited from a University.
Imperatori et al. (2015)	N=28 overweight or obese adults. N=14 with ≥3 YFAS symptoms, N=14 with ≤2	YFAS (Italian version), psychiatric interview, FCQ-T-r, HADS, hunger VAS, EEG responses to chocolate milkshake and neutral solution	14.29% met YFAS criteria for FA (N=4)				High FA group increased activation in gyrus and insula following milkshake compared to low YFAS group. Differences not seen in neutral condition			Low FA prevalence in OW/OB sample, possibly due to low sample size or exclusion of those with eating disorders (e.g., BE)

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Imperatori et al. (2016)	N=301 overweight and obese females seeking low-energy-diet therapy	CTQ, YFAS, BES, HADS, (Italian versions) BMI	25.2% met the YFAS criteria for FA (N=76)						YFAS was positively correlated with CTQ, BMI, depression, anxiety, binge eating severity. More severe CT was predicted higher YFAS score	BE was also significantly associated with childhood trauma, including the sexual abuse subscale which was not associated with YFAS
Innamorati et al. (2017)	N=322 adults	YFAS, DERS, MZQ, BES, MAST (Italian versions)		3.7% met the YFAS criteria for FA (N=12)					High YFAS group had poorer emotion regulation and mentalization deficits. YFAS negatively correlated with alcohol risk	Grouped participants according to more than or fewer than 3 YFAS symptoms rather than dichotomous criteria or median split
Ivezaj, White & Grilo (2016)	N=502 overweight or obese adults (83.2% F)	Self-report BMI, EDE-Q, YFAS, BDI, BIS-11, BSCS	26.7% met YFAS criteria for FA (N=134)				The ED groups had higher scores on all clinical variables compared to control group		BED and FA groups had greater BDI scores than controls	ED groups did not differ from one-another on eating behaviour or wellbeing variables

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Ivezaj, Potenza, Grilo & White (2017)	N=1000 adults (86.8% F)	EDE-Q, YFAS, BDI, BIS-11, BSCS					Sub-ED group and at-risk internet use groups had higher YFAS scores than control group			Did not report YFAS prevalence. Problematic internet use possible comorbid problem
Joyner, Gearhardt & White (2015)	283 adults (83% F)	Self-report BMI, YFAS, FCI, EDE-Q					Food craving was a significant partial mediator between addictive-like eating and BMI, and between addictive-like eating and binge eating			Craving is independently associated with BMI and binge eating, therefore an addictive element to overeating is redundant
Joyner, Schulte, Wilt & Gearhardt (2015)	N=257 US adults (51.4% F) ranging in BMI	YFAS, PEMS, self-report BMI					YFAS was a significant complete mediator between Coping, Enhancement, and Social motivations for eating and BMI and a partial mediator between Conformity motivations for eating and BMI			Did not report YFAS prevalence. Did not measure BE which could account for some of the variance in PEMS scores.

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Karlsson et al. (2016)	N=16 morbidly obese females undergoing bariatric surgery, and N=14 non-obese female controls	STAI, YFAS, DEBQ, PET scanning (not related to YFAS)						Obese group had significantly higher YFAS scores pre-surgery compared to controls. YFAS scores significantly decreased post-surgery		Small sample size. Surgery reduced YFAS points to similar level as non-obese controls
Keser et al. (2015)	N=100 overweight and obese children and adolescents (63% F)	Measured BMI and anthropometrics YFAS (Turkish translation), FFQ				71% met YFAS criteria for FA	Experiencing frequent feelings of hunger was associated with a 2.2x increase in FA risk			YFAS, not YFAS-C was used despite child and adolescent sample
Kozak, Davis, Brown & Grabowski (2017)	N=190 US adults, normal weight to obese (54.2% F) N=152 completed YFAS	Lifestyle questionnaire, measured BMI, DTS, DEBQ, TFEQ, YFAS					Positive correlation between YFAS and DEBQ, TFEQ	Positive correlation between YFAS and BMI	YFAS was negatively correlated with distress tolerance	Relationship between DT and FA only present in those who overeat therefore FA could simply be measuring a degree of overeating
Laurent & Sibold (2016)	N=65 children (60% F), N=50 completed YFAS-C	Measured BMI, YFAS-C, C-PFS, C-PAQ, DEBQ-child, CDI, MASC				4% met YFAS criteria for FA (N = 2)	YFAS significantly correlated with PFS and DEBQ	No correlation between YFAS and BMI	YFAS significantly correlated with CDI	Very low prevalence of FA in children

Authors	Sample	Measures	Prevalence: Obese or overweight	Prevalence: General population	Prevalence: Eating or Psychiatric disorders	Prevalence: Children/ adolescents	Correlates: Problematic eating	Correlates: Weight loss/ BMI	Correlates: Psychological wellbeing	Critical analysis
Loxton & Tipman (2017)	N=374 females	SR, PFS, DEBQ, BEQ, YFAS		5.34% met YFAS criteria for FA (N=20)			YFAS significantly correlated with binge, external and emotional eating and PFS	YFAS significantly correlated with BMI	YFAS significantly correlated with reward sensitivity, impulsivity, anxiety, depression and stress	Low prevalence in general population. relationship between YFAS and reward sensitivity moderated by binge eating, emotional eating and food availability
Markus, Rogers, Brouns & Schepers (2017)	N=1495 University students	YFAS, BDI, self-report BMI (half participants checked in lab)		12.6% met YFAS criteria for FA			YFAS symptoms predicted greater BMI in participants reporting overeating HFSA and HFSW foods	YFAS significantly correlated with BMI	YFAS significantly correlated with depression in those participants endorsing at least one YFAS symptom (N=1414)	No specific 'addicitve' behaviours towards sugar, therefore no evidence for 'sugar addiction'. Sugar and fat in combination (i.e., high ED foods) more craved and overeaten

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Meadows, Nolan & Higgs (2017)	Study 1a: N=658 University students (90% F), Study 1b: 305 University students in follow-up analysis (92% F) Study 2: 614 adults (59.8% F)	Self-perceived FA, YFAS, diet status, RS, ESES, IES, EAT, MBSRQ-AS, AFAQ-R, WSSQ, Validation-Seeking subscale, self-report BMI		S1a: 8.5% S1b: 7.5% S2: 13.7% met YFAS criteria for FA			Self-perceived FA was more prevalent than YFAS FA. Lack of self-control differentiated between SPFA who did and did not meet YFAS criteria			FA higher in adult population compared to student
Moran et al. (2016)	999 adults (47.6% F)	Beliefs about addictive potential & obesity, policy political and industry support, YFAS, Hong's 11-item psychological reactance scale,		5.1% met YFAS criteria for FA (N=51)						Did not include YFAS in models predicting obesity-related policy support
Nolan & Geliebter (2016)	N=254 students and N=244 adults	NEQ, YFAS, SDS, PSQI		5.1% of the students and 18.7% of the community sample met YFAS criteria for FA			YFAS correlated with NEQ scores (except morning anorexia in students). High YFAS predicted increased NE			Strong associations again question whether FA is a unique condition

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Pedram et al. (2017)	Study 1: N=8 obese with high YFAS score, N=8 obese with low/no YFAS score, N=8 healthy weight controls Study 2: N=752 adults	Anthropometrics, YFAS, genomic DNA isolation, Baecke physical activity questionnaire					DRD2 gene on and toll-interleukin 1 receptor (TIR) domain containing adaptor protein) on chromosome 11 identified as related to increasing YFAS score			Small sample size in stage 1 means candidate genes could have been missed. No info on comorbidities e.g., binge eating
Pivarunas & Conner (2015)	878 University students (69.2% F)	YFAS, UPPS Impulsive Behavior Scale, DERS,		4.5% met YFAS criteria for FA (N = 39)					Negative urgency and DERS total score positively predicted YFAS symptom count and lack of premeditation negatively predicted YFAS score	Sample limited to University students only
Polk, Schulte, Furman & Gearhardt (2017)	N=216 US adults (61.6% F)	Self-report BMI, TFEQ, YFAS, craving and liking of 35 food images					YFAS score was a small, positive predictor of the association between reported craving and processing. YFAS score did not significantly impact liking ratings.			Dissociation between craving and liking. Individuals with high YFAS scores crave foods more, but high cravings do not equate to an addiction

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Price, Higgs & Lee (2015)	N=496 UK adults (73.8% F)	Self-report BMI, PFS, EES, TFEQ, DEBQ, BIS, YFAS					YFAS correlated significantly with all measures except TFEQ cognitive restraint. YFAS loaded onto 'food reward responsivity' subscale			YFAS 'sum score' used in principal components analysis
Price, Higgs, Maw & Lee (2016)	N=79 University staff/students		Mean 'symptom count' of 1.89 (±1.5)	Mean 'symptom count' of 1.49 (±0.66)						No critical analysis of YFAS scores included
Pursey, Collins, Stanwell & Burrows (2015)	N=462 Australian adults (86% F)	YFAS, Australian Eating Survey food frequency questionnaire		14.7% met YFAS criteria for FA (N = 68)			No differences in EI between FA and non-FA groups. %EI from total fat and mono-unsaturated fat was associated with higher odds of classification as FA			Weak evidence for differing nutrient intake across FA/non-FA groups

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Pursey, Collins, Stanwell & Burrows (2016)	N=69 participants followed-up from previous survey (94.2% F)	YFAS, alcohol consumption and weight loss behaviour questions		15.9% met YFAS criteria for FA (N = 11)						Only 7 participants met YFAS criteria for FA at baseline and follow-up, therefore YFAS does not appear to be stable over time
Pursey, Gearhardt & Burrows (2016)	N=93 females	YFAS, measured body composition		22.3% met YFAS criteria for FA (N = 21)				YFAS score was moderately correlated with visceral fat area and YFAS score predicted increases in visceral fat area		Problematic eating as measured by the YFAS appears to predict increasing adiposity
Raymond & Lovell (2015)	N=334 adults with type 2 diabetes (65.6% F)	DASS-21, BIS-11, YFAS			70.7% met YFAS criteria for FA			FA subjects had higher BMI. YFAS score and impulsivity (non-planning) significantly predicted BMI		Majority of sample were overweight/ obese therefore high FA prevalence is likely to be related to BMI, rather than T2d

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Raymond & Lovell (2016)	N=334 adults with type 2 diabetes (65.6% F)	DASS-21, BIS-11, YFAS							FA group had higher depression, anxiety, and stress scores and YFAS was significant predictor of these scores	Same study as Raymond & Lovell (2015)
Richmond, Roberto & Gearhardt (2017)	N=70 children (42.9% F)	Dinner meal consumption, YFAS-C, eating habits questionnaire, AMPM dietary recall						YFAS score was positively associated with EI at dinner and post-dinner. This relationship was moderated by age whereby younger children only demonstrated this effect		Did not report YFAS prevalence
Ruddock, Field & Hardman (2017)	N=60 female University students	Measure of self-perceived FA (SPFA), VAS of test foods, TFEQ, BES, YFAS					SPFA had higher YFAS scores but were not more likely to fulfill the YFAS criteria for FA, relative to SP non-FA			Recruitment was targeted to ensure approx. half SPFA and half non-SPFA

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Sanlier, Türközü & Toka (2016)	793 students (605 F)	Body image scale, YFAS, BDI (Turkish translations), measured BMI		10.5% met YFAS criteria for FA (N=83)				YFAS correlated with BMI	YFAS correlated with depression score	Turkish translations of scales not validated. University sample
Sawamoto et al. (2017)	N=86 OW/OB females in a weight loss intervention follow-up	Weight loss intervention, health assessment, CES-D, STAI, BES, TFEQ, YFAS,						YFAS scores of the successful WL subjects post-intervention were sig. lower than unsuccessful subjects. Successful weight loss maintenance was associated with a lower food addiction score post-intervention.		Did not provide data on the impact of pre-intervention YFAS score on WL or WLM
Schulte, Tuttle & Gearhardt (2016)	N=193 subjects (58.5% F)	Belief in FA, Support for Obesity-Focused Policy Initiatives, mYFAS					YFAS score was positively correlated with belief in food addiction			Did not report YFAS prevalence.

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Sevinçer, Konuk, Bozkurt & Coşkun (2016)	N=166 bariatric surgery candidates (77.1% F)	YFAS	57.8% met YFAS criteria for FA pre-surgery. (N=96) 7.2% met YFAS criteria at 6mo follow-up (N=6). 13.7% met YFAS criteria at 12mo follow-up (N=7)					YFAS score decreased significantly from pre-operation to 6 and 12 month follow-up		No differences between FA and non-FA in WL at follow-up, therefore YFAS cannot be accountable for WL success
Steward et al. (2016)	N=28 adults (N=14 normal weight, N=14 overweight/ obese)	fMRI task, ERQ, BIS-11, YFAS, BIS/BAS					YFAS score was significantly higher in overweight group compared to normal weight			Did not report YFAS prevalence or analyse effect of YFAS score on fMRI activity
Tang & Koh (2017)	N=1110 students (N=694 F)	BFAS, mYFAS, compulsive buying scale, DSM-5 measures of Depression, anxiety and mania		4.7% met YFAS criteria for FA (N=52)					FA co-occurred with social media 'addiction' (3%)	Over-medicalisation of behavioural addictions
VanderBroek-Stice et al. (2017)	N=181 adults (71.3% F)	Measured BMI, YFAS, UPPS-P, go/no-go task, monetary delay discounting task		6.6% met YFAS criteria for FA (N=12)				YFAS score correlated positively with obesity	Impulsivity and discounting of delayed rewards were independently significantly associated with FA	Associations between impulsivity and obesity are not new

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	
Weinstein, Zlatkes, Gingis & Lejoyeux (2015)	N=60 females enrolled in the Overeaters Anonymous Self-Help Program	YFAS, STAI, BDI, self efficacy scale						YFAS score was lower after 1 year of treatment compared to the beginning of treatment, but not after 5 years	YFAS correlated with depression, anxiety and self-efficacy	Poor results of OA in reducing YFAS scores suggests no addictive element to overeating
Wolz et al. (2016)	N=278 eating disorder patients (N=258 F)	YFAS, UPPS-P, TCI-R, EDI-2, measures of behavioural and substance addictions							ED patients with FA have lower self-directedness and higher scores on lack of perseverance and negative urgency	Did not report FA prevalence. Sample limited to ED patients only
Wolz, Granero & Fernández-Aranda (2017)	N=315 adults with BED or BN (N=292 F)	YFAS, UPPS-P, TCI-R, EDI-2, DERS							Negative urgency only independent predictor of YFAS score	Did not report FA prevalence. Sample limited to BE patients only

Authors	Sample	Measures	Prevalence				Correlates			Critical analysis
			Obese or overweight	General population	Eating or Psychiatric disorders	Children/ adolescents	Problematic eating	Weight loss/ BMI	Psychological wellbeing	

Legend: YFAS = Yale Food Addiction Scale; YFAS-C = Yale Food Addiction Scale for Children; CDI = Child Depression Inventory; SCARED = Screen for Child Anxiety Related Disorders; BMI = body mass index; BES = Binge Eating Scale; TFEQ = Three Factor Eating Questionnaire; DSM = Diagnostic and Statistical Manual (of Mental Disorders); ED = eating disorder; BED = Binge Eating Disorder; NES = Night eating syndrome; EDE = eating disorder examination; EDE-Q = eating disorders examination questionnaire; DEBQ = Dutch eating behaviour questionnaire; EAH = eating in the absence of hunger questionnaire; WBIS = weight bias internalisation scale; DERS = Difficulties in Emotion Regulation Scale; EDDS = Eating Disorder Diagnostic Scale; BDI-FS = Beck Depression Inventory-Fast Screen; QOLOD = Quality Of Life, Obesity and Dietetics scale; BDI = Beck Depression Inventory; CFQ = Child feeding questionnaire; API = Addiction profile index; BIS = Barratt impulsivity scale; EAT = eating attitudes test; WLT = weight loss treatment; QEWP = Questionnaire on Eating and Weight Patterns; IWQOL-Lite = Impact of Weight on Quality Of Life-Lite; PHQ-9 = Patient health questionnaire; BIS/BAS = behavioral inhibition system/behavioral approach system; EEG = Electroencephalographic recording; EES = Emotional eating scale; SCL = Symptom Checklist Revised; EDI = eating disorders inventory; FCQ-T-r = Food Cravings Questionnaire-Trait-reduced; HADS = Hospital Anxiety and Depression Scale; CTQ = Childhood Trauma Questionnaire; MZQ = Mentalization Questionnaire; MAST = Michigan Alcohol Screening Test; BSCS = Brief Self-Control Scale; PEMS = Palatable Eating Motives Scale; FCI = Food cravings inventory; FFQ = food frequency questionnaire; DTS = Distress Tolerance Scale; C-PFS = Children's Power of Food Scale; C-PAQ = Children's Physical Activity Questionnaire, CDI = Children's Depression Inventory; MASC = Multidimensional Anxiety Scale for Children; SR = Sensitivity to Reward Scale; BEQ = binge eating questionnaire; RS = restraint scale; ESES = Eating Self-Efficacy Scale; IES = Intuitive Eating Scale; MBSRQ-AS = Multidimensional Body Self-Relations Questionnaire - Appearance Scales; AFAQ-R = Anti-Fat Attitudes Questionnaire-Revised; WSSQ = Weight Self- Stigma Questionnaire; NEQ = night eating questionnaire; SDS = Self-report Depression Scale; PSQI = Pittsburgh Sleep Quality Scale; DASS = Depression Anxiety Stress Scale; AMPM = Automated Multiple Pass Method; CES-D = Center for Epidemiologic Studies-Depression Scale; STAI = State-Trait Anxiety Inventory; BFAS = Bergen Facebook Addiction Scale; TCI-R = Temperament and Character Inventory-Revised.

Appendix C

The two factors identified in the PCA, their respective items and DSM-IV-TR criteria

PCA Factor 1		PCA Factor 2	
Item	DSM/YFAS criteria	Item	DSM/YFAS criteria
3 - I eat to the point where I feel physically ill	Substance taken in larger amount and for longer period than intended	19 - I kept consuming the same types of food or the same amount of food even though I was having emotional and/or physical problems.	Use continues despite knowledge of adverse consequences (e.g., failure to fulfil role obligation, use when physically hazardous)
5 - I spend a lot of time feeling sluggish or fatigued from overeating	Much time/activity to obtain, use, recover	20 - Over time, I have found that I need to eat more and more to get the feeling I want, such as reduced negative emotions or increased pleasure	Tolerance (marked increase in amount; marked decrease in effect)
7 - I find that when certain foods are not available, I will go out of my way to obtain them.	Much time/activity to obtain, use, recover	21 - I have found that eating the same amount of food does not reduce my negative emotions or increase pleasurable feelings the way it used to.	Tolerance (marked increase in amount; marked decrease in effect)
8 - There have been times when I consumed certain foods so often or in such large quantities that I started to eat food instead of working, spending time with my family or friends, or engaging in other important activities or recreational activities I enjoy.	Important social, occupational, or recreational activities given up or reduced	22 - I want to cut down or stop eating certain kinds of food	Persistent desire or repeated unsuccessful attempts to quit
		25 - How many times in the past year did you try to cut down or stop eating certain foods?	Persistent desire or repeated unsuccessful attempts to quit

Appendix D
Demographic information about the sample used in Chapters 3 and 4, split by gender

Independent samples t-tests were conducted to compare scores on all domains between males and females, as outlined in the *t*-test column.

Measure		Total sample (N=667)		Males (N=119)		Females (N=548)		*t*-test
		Mean	SD	Mean	SD	Mean	SD	*t*
Age		26.24	11.05	30.66	12.55	25.32	10.47	4.87***
Self-reported weight (kg)		65.71	15.72	79.57	18.13	62.70	13.38	11.64***
YFAS ‘symptom count’		1.88	1.45	1.38	1.01	1.99	1.50	-4.20***
YFAS ‘sum-score’		2.85	2.83	1.80	1.64	3.08	2.98	-4.56***
BES		9.94	8.25	6.17	5.54	10.76	8.51	-5.63***
CoEQ	Craving Control	59.68	23.65	69.58	21.65	57.52	23.53	5.14***
	Craving Sweet	44.38	24.62	35.90	23.37	46.22	24.52	-4.20***
	Craving Savoury	46.01	21.49	43.33	20.64	46.60	21.64	-1.51
	Positive Mood	61.13	17.03	64.78	17.14	60.44	16.94	2.23*
TFEQ Disinhibition		7.18	3.97	5.33	3.12	7.58	4.02	-5.74***
PFS		2.67	.89	2.34	.78	2.74	.90	-4.55***
EDE Restraint		1.32	1.29	.92	1.12	1.40	1.30	-3.75***

QOL	Physical Health	16.15	2.35	16.33	2.43	16.11	2.33	.91
	Psychological	14.13	2.78	14.27	2.85	14.10	2.77	.60
	Social Relationships	14.77	3.18	14.42	3.24	14.85	3.16	-1.34
	Environmental	15.66	2.01	15.61	1.99	15.67	2.01	-.27
BDI		9.35	7.93	8.23	7.61	9.59	7.99	-1.70
PSS		15.93	7.00	13.72	6.71	16.41	6.98	-3.84***
STAI	State	37.25	10.97	34.15	9.65	37.92	11.13	-3.43**
	Trait	41.25	11.97	37.73	11.03	42.02	12.04	-3.57***
APP		7.66	3.44	9.12	3.50	7.34	3.35	5.19***
AUDIT		8.86	5.63	9.25	6.44	8.78	5.44	.83
DAST		1.01	1.85	1.13	2.00	.98	1.81	.82

* $p < .05$, ** $p < .01$, *** $p < .001$

Appendix E
List of foods included in the perceptions platform (Chapter 5)

Kiwi	Pretzels	Fried Chicken	Crisps
Dried Apricots	Cheese Pizza	Steak	Tuna
Corn on the Cob	Crackers (plain)	Chicken Breast	Fine Beans
Avocado	Granola Bar	Marshmallows	Cod Fillet
Apple, Green	Pasta	Croissant	Chips
Grapefruit, Pink	Ryvita	Milk Choc	Salmon
Pineapple	Bread Roll	Jelly Babies	Hummus
Banana	White Toast	Biscuit/Cookie	Boiled Egg
Orange	Porridge	Digestive	Cheese Burger
Strawberries	Cornflakes (no milk)	Flapjack	Butter Beans
Grapes	Brown Bread	Sultana Scone	Bacon
Carrots	Natural Yoghurt	Angel Cake	Burger
Brocolli	Brie	Blueberry Muffin	Cashew nuts
Cucumber	Cheesestrings	Doughnut	Popcorn
Potatoes	Cheddar	Scotch Pancake	Ice Cream
Sweet Potato	Custard	Jelly	Baked Beans
White Basmati Rice	Whipped Cream	Fudge	Brownie
Brown Wholemeal Rice (plain)		Cottage Cheese	

Appendix F

Time points at which the appetite and mood ratings were taken throughout the test day (Chapter 6)

Rating	Event	Time (minutes)
1	Pre-breakfast (baseline)	0
2	Post-breakfast	15
3	+1-h	60
4	+2-h	120
5	Pre-preload	180
6	Post-preload	195
7	Pre-lunch	240
8	Post-lunch	255
9	+1-h	300
10	+2-h	360
11	+3-h	420
12	Pre-dinner	480
13	Post-dinner	495
14	+1-h	540

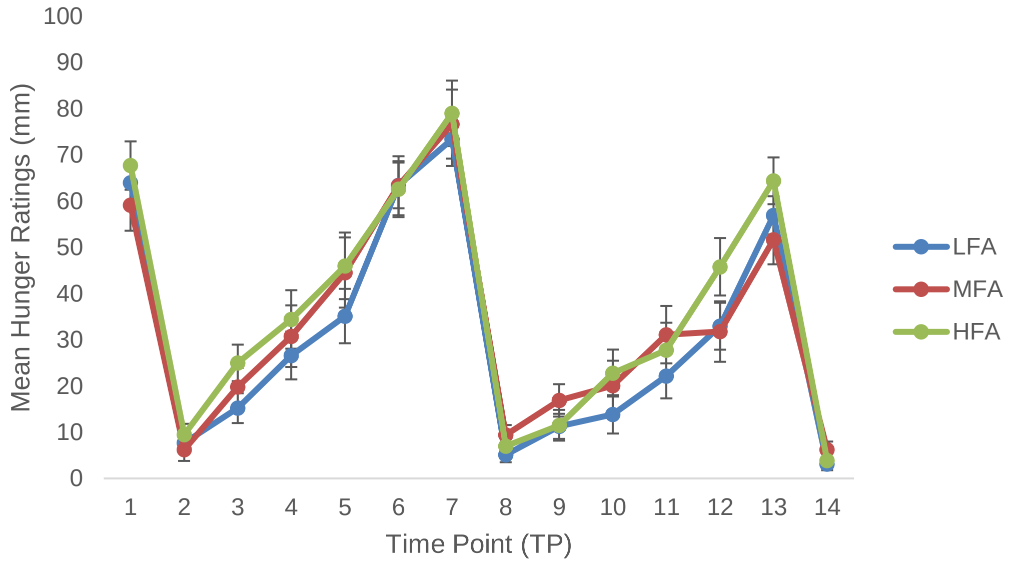
Appendix G

Time points at which the appetite and mood ratings were taken throughout the test day (Chapter 7)

Rating	Event	Time (minutes)
1	Pre-breakfast (baseline)	0
2	Post-breakfast	15
3	+1-h	60
4	+2-h	120
5	+3-h	180
6	Pre-LFPQ1	220
7	Post-LFPQ1/Pre-Lunch	235
8	Post-Lunch/Pre-LFPQ2	260
9	Post-LFPQ2	275
10	+1-h	340
11	+2-h	400
12	+3-h	460
13	Pre-dinner	520
14	Post-dinner	545

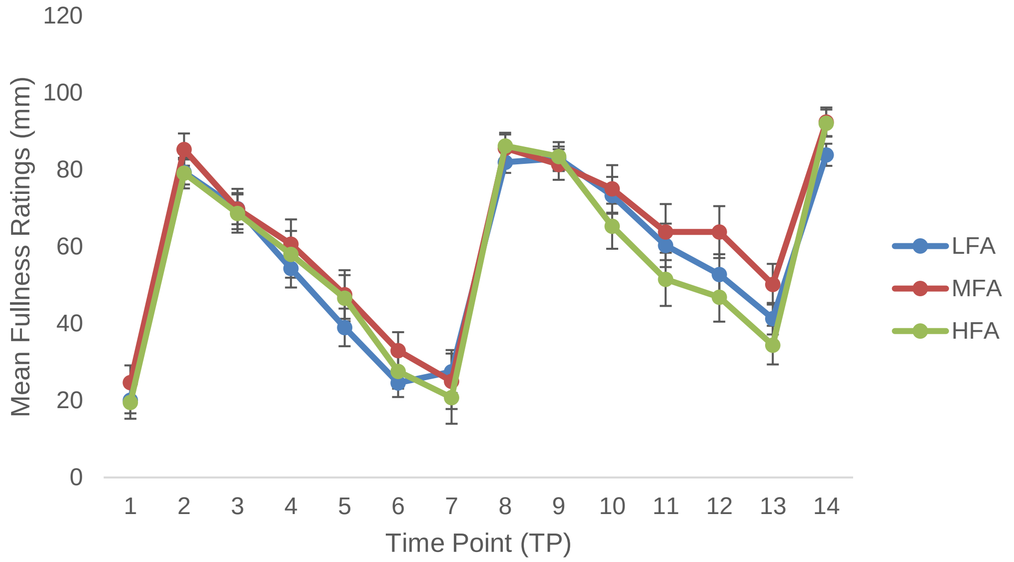
Appendix H

Hunger ratings across the day for the LFA, MFA and HFA groups. Note: lines denote Standard Error (Chapter 7)



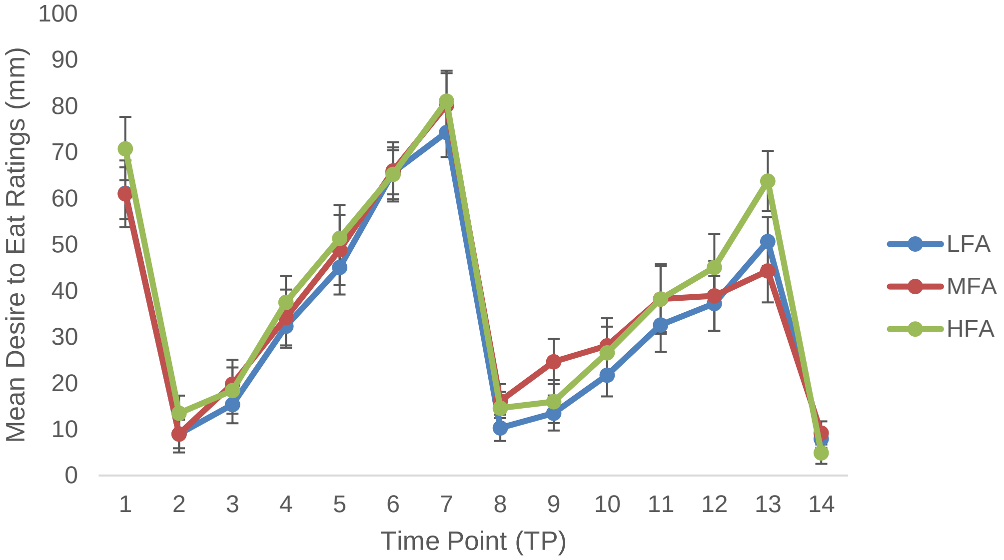
Appendix I

Fullness ratings across the day for the LFA, MFA and HFA groups. Note: lines denote Standard Error (Chapter 7)



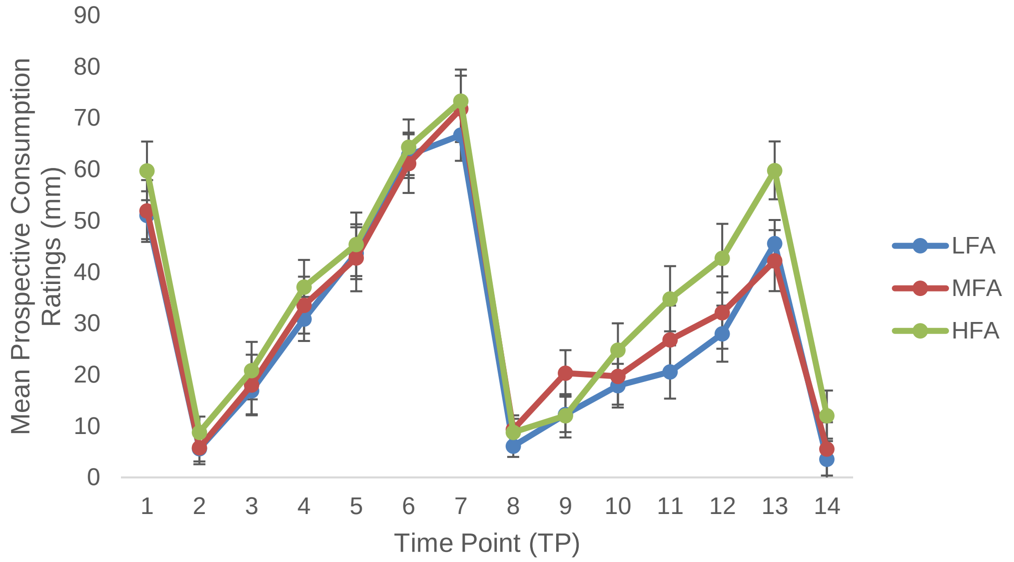
Appendix J

Desire to eat ratings across the day for the LFA, MFA and HFA groups. Note: lines denote Standard Error (Chapter 7)



Appendix K

Prospective consumption ratings across the day for the LFA, MFA and HFA groups. Note: lines denote Standard Error (Chapter 7)



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