NEUROCOGNITIVE MEASURES OF IMPULSIVITY: EXPLANATORY, DIAGNOSTIC AND A PROGNOSTIC ROLE IN OBESITY

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Declaration of Originality

All of the work in this thesis is my own and all else is appropriately referenced.

Copyright Declaration

Outputs from Thesis

Peer-reviewed article journals

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Departmental Talks and Seminars

1. Impulsivity and Obesity: a theoretical framework, Departmental Presentation, Department of Surgery and Cancer, Nov 2011.
2. The mediating and moderating role of impulsivity in obesity. Centre for Health Policy, Imperial College London, Aug 2012.
3. Change in impulsivity during a residential multi-dimensional weight loss camp for obese adolescents, Christmas Presentation, Department of Surgery and Cancer, Imperial College London, Dec 2012.
4. Systematic Review: Impulsivity in obesity as measured by inhibitory control. Bariatric Research Meeting, St Mary's Hospital, London. Jan 2014

5. Neurocognitive measures of impulsivity: explanatory, diagnostic and prognostic role in obesity. Department of Surgery and Cancer, Imperial colge London, Jan 2014.

Regional Presentation

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National Presentations

1. The association between cognitive behavioural therapy and impulsivityin an adolescent obesity camp. Lancet Public Health Science Conference, London, Aug 2012.
2. Inhibitory control and perception of the future health in obese adolescents and normal weight adolescents. Lancet Public Health Science Conference, London, Aug 2012.

International Presentations

1. Change in impulsivity and subjective wellbeing in a residential camp for obese adolescents. Obesity Society, San Antonio, USA, Nov 2012
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ABSTRACT

Obesity is a growing public health problem with multiple aetiological factors. Behavioural determinants are likely to be key contributors to obesity, with a need for applied research in this field. Recently the obesity has been compared to food addiction with the connotation that obese individuals are impulsive in their behaviour. Impulsivity is a trait that is closely linked to addiction and has been studied in personality, psychiatry and more recently in the neurocognitive arena.

A conceptual review of the construct of impulsivity identified inhibitory control (SST) and temporal discounting (TD) as two key behavioural constructs universal to all the key fields of impulsivity research. A systematic review of the literature supported their use to profile participants based on their Body Mass Index. The validity of the tools were proven by endophenotyping participants (N=202) of both normal weight and those seeking weight loss intervention. Both measures could successfully differentiate between obese and normal weight adolescents (N=85). The SST was also prognostic for short-term weight reduction in adolescents attending a lifestyle intervention, with the TD being able to predict weight loss maintenance at 6 months. The tasks could not differentiate significantly between adults of different weights but the TD was able to predict weight reduction after surgery (N=90). The modifiability of obesity through neuronal dopamine pathways was supported by a randomised controlled trial testing neurocognitive enhancement agents (N=40) against a placebo (N=40) in normal weight adults. Weight was also controlled by a commitment intervention targeting automatic impulsive behaviours (N=27).

These findings support an association between impulsivity, obesity and weight reduction. The experimental inferences have been described in terms of a novel interconnected neuronal network, which leaves itself open to testing using functional brain imaging.

Chapter 1 Aetiology of Obesity

1.1 Obesity definition

Obesity is a term used to describe an individual who is grossly very overweight with a high degree of body fat, which may have an adverse effect on health (WHO/International Taskforce for Obesity). Body Mass Index (BMI) is the recommended approach to assessing body size in the clinical setting, providing a more accurate measure of body size than weight alone. It is minimally correlated with height and highly correlated with body fat percentage and the levels of disease risk of comorbidities. BMI is calculated by dividing an individual's weight in kilograms by their height in metres squared. Those with a BMI between 25 and 29 are considered overweight, 30 to 40 obese, and a BMI over 40 would be considered to be morbidly obese.

1.2 Why obesity is an important global issue

According to the World Health Organisation, obesity is the fifth leading risk for global deaths, with the number of obese people increasing every year. In the United States the percentage of adolescents aged 12-19 year who were obese increased from 5% to 18% over the same period (Ogden, Carroll, Kit, & Flegal, 2012). In 2008, an estimated 1.46 billion adults were overweight globally and a further 502 million were obese (Finucane et al., 2011). Obesity is predominately a condition affecting those from a lower socioeconomic status in middle to high-income countries (Wang & Beydoun, 2007). The higher the income inequality within a country, the higher the prevalence of obesity. Being obese increases a person risk of developing a number of serious and potential life-threatening diseases (co-morbidities) such as diabetes, heart disease, cancers and stroke. The World Health Organisation has calculated that obesity and its accompanying complications are attributable to 36 million disability adjusted life years (WHO, 2004) and in some countries obesity has overtaken smoking as the number one contributor to health costs (Hoad, Somerford, & Katzenellenbogen, 2010). Despite the consequences of obesity being acknowledged as a rising health problem, we are yet to identify a solution.

1.3 Causes of obesity

1.3.1 Genetics

Genetics is likely to play a significant role in obesity. Evidence suggests that genetic factors may operate largely through appetite control. Genetic variation determines our metabolism, appetite and tolerance of physical activity. Twin and adoption studies support genetics to be a major contributor to an individual's BMI. A study which assessed the heritability of BMI in over 20,000 young adult twin pairs from eight European countries found that the correlation of BMI between identical twins ranged from 0.65 to 0.83, which was significantly stronger than that between non-identical same sex twins (0.31-0.58). The estimate genetic effect was 60-70% when age and sex difference were accounted for. Similar trends have been shown in the UK. In a systematic review of five adoption studies comparing parent-biological child versus parent-adoptee comparisons, it was shown that child BMI was consistently strongly correlated with that of their biological parents than of their adoptive parents. Genome studies have identified 32 regions of the human genome associated with body mass index, with the DNA variant in the FTO gene having the strongest association (Almén et al., 2012). Individuals with two copies of the allele are on average 0.5 BMI point heavier than those carrying two copies of the protective version. The FTO is thought to have a stronger effect on those who are sedentary than those who are more physically active, as the FTO genotype may affect energy balance by influencing behaviour (Tanofsky-Kraff et al., 2009). A single genetic cause for common obesity not secondary to an underlying disorder has not yet been found. However, the role of behaviour and the environment on epigenetic factors is still being investigated.

1.3.2 Environmental

In order for an environment to be implicated in the rise in obesity, it would have had to change sufficiently over the last 40 years in parallel with the obesity epidemic and be a global phenomenon. There has been a rise in industrialisation and a significant change in transport modality from walking to motor vehicles.

Built Environment

The built environment itself is unlikely to be a primary cause of the obesity epidemic. However, individual's behaviour to industrialisation and a reduction in active transport may contribute to the rise in obesity.

Food Systems

A change in the Food system to allow for an increase in cheap and highly palatable processed foods with improved food marketing is a likely driver of the obesity epidemic. Therefore, an abundance of food has led to a positive energy balance for the overall population (Hall et al., 2009; Swinburn et al., 2009; Scarborough et al. 2011). Such a varied choice in food often processed and unhealthy can lead to passive overconsumption. Although an oversimplification the final decision on whether to eat or exercise is an individual choice. It has been postulated that many of such behaviours are automatic or subconscious with underlying neuropsychological mechanisms in response to eating and physical activity opportunities.

Body size preference

Cultural body size preference can affect who becomes obese with increased food access. In Tongan women, a large habitus is preferred whereas in Japanese women it is the opposite (Becker, Burwell, Herzog & Hamburg, 2002).

Lifestyle

Too little sleep and impaired sleep quality have been shown to have impaired effects on weight gain (Chaput, Després, Bouchard, & Tremblay, 2008).

1.3.3 Non-psychological predictors

BMI

Initial BMI has been postulated to be a positive predictor (higher initial BMI, larger weight loss) of weight loss (Committee to Develop Criteria for Evaluating the Outcomes of Approaches to Prevent and Treat Obesity, Institute of Medicine).

Dieting

Previous dieting and frequent weight loss attempts are a negative prospective correlation of weight loss (Wadden et al., 1992; Foreyt et al.,1995; Kiernan et al., 1998).

Social Support

Studies show a group treatment setting varying from intensive closed groups such as university clinics to informal commercial style settings can be more efficacious than dieting alone. There is significantly greater weight loss in groups setting even when the participants preferred individual treatment (Perri et al., 2001). The involvement of family and friends in-group treatment also has benefit to weight loss. A study tracking 166 people interested in weight loss found that two-thirds of participants who enrolled with friends and who were given social support in addition to standard behavioural treatment were able to sustain their weight six months after the intervention (Wing & Jeffery, 1999)

Transition points in Life

Many individuals who are obese have attempted to lose weight at multiple and various time in their life. The Foresight (2007) report has identified times of transition during one's life where intervention may be necessary and be more successful. Therefore there may be an optimum time for one to engage in weight loss activities during the life cycle.

1.4 Why study psychological predictors?

It can be beneficial to optimise weight loss for those entering programmes by being able to screen for psychological characteristics. Such profiling also provides an indication for an individual's aptitude and willingness to adhere with advice strategies. By measuring baseline psychology one can optimise efficacy of the intervention by matching the strategy type and duration to the measured patient profile or characteristic. For example, a young person with poor self-control over eating may benefit from a community intervention, which practices self-control with a focus on implementation intentions and extra maintenance therapy using Short Message Service (SMS) to help with long-term weight loss. Secondly, pre-treatment screening could identify individual's readiness and likeliness to lose weight. This prevents them from any unnecessary disappointment from further failed attempt and saves resources.

1.5 Psychological Predictors

1.5.1 Depression

Mood disorders, particularly depression, are known to affect the physiological function of the body, including appetite and body weight regulation (Carey, et al., 2014). In addition, it is also a major cause of morbidity worldwide. Lifetime prevalence estimates of depression vary widely, from 3% in Japan, to 17% in the US, with the majority of other countries in the range of 8% to 12% (Kessler et al., 2003). Melancholic or typical depression is associated with weight loss and decreased appetite, while the opposite is seen in atypical depression.

There is a significant positive association between obesity and depression in the general population, which appears to be more marked in women (De Wit et al., 2010). In adolescence, the presence of major depression or any mood disorder predicted a 2 to 3 times increase in risk of obesity (Wilson & Goldfield, 2014). Furthermore, obesity is a major risk for developing type 2 diabetes mellitus, which increases the risk of depression on its own (Mezuk, Eaton, Albrecht & Golden, 2008).

It is evident that depression and obesity have a reciprocal relationship, although the exact mechanism is unknown (Mamorstein, Iacano & Legrand, 2014). It is suggested that depressed people develop obesity over time due to a change in lifestyle (Luppino, de Wit, Bouvy, Stijnen, Cuijpers, Penninx & Zitman, 2010). Depression causes a reduction in physical activity, induces eating behaviour changes, and stimulation of the stress systems. In addition, obesity may also be caused by endocrine disturbances. When depressed, the body undergoes chronic activation of the hypothalamic-pituitary-adrenal (HPA) axis, which is similar to a stress response. Long term activation of the HPA-axis induces chronic high levels of cortisol, which inhibits lipid-mobilising enzymes, causing an increase in abdominal fat deposition (Bjorntop, 1996).

1.5.2 Stress

Stress can be defined as the generalized, non-specific response of the body to any factor that overwhelms, or threatens to overwhelm, the body's compensatory abilities to maintain homeostasis. The body's main stress reactor systems are the active flight-or-fight pattern, via the sympathetic adrenal medullary system (SAM), and the passive system, which involves the hypothalamic-pituitary-adrenal axis (HPA) (Puder & Munsch, 2010).

SAM is dominant in periods of acute stress, releasing catecholamines, while the hyperactivation of the HPA axis occurs during chronic stress, with the release of corticosteroids. Regardless of the type of stress, the individual usually undergoes physiological changes, including slowed gastric emptying, elevation of blood pressure, increase in heart rate, mobilization of energy stores, and decrease in blood flow to non-essential organs, e.g., the digestive system, kidneys, and skin.

However, there are also differences in the effects of chronic and acute stress due to the different stress hormones being released. While noradrenaline (SAM) and corticotrophin-releasing-hormone (HPA) suppress appetite during stress, cortisol is known to stimulate appetite during recovery periods from stress. Consequently, stress effects are bidirectional, some people lose food intake and weight (30%), while the others have increased appetite and weight gain during stress (Torres & Nowson, 2007). In stress-related animal studies, stress increases the intake of palatable foods

(Gluck, 2006). Given the abundance of high-calorie palatable food in many Westernised countries, it is no surprise that there is a rise in the incidence of obesity.

1.5.3 Addiction

Overeating displays a huge amount of similarity to substance dependence, and as a result, food addiction has been viewed by some as a model for weight gain and obesity (Jauch-Chara & Oltmanns, 2014). Obese subjects have been found to ingest greater amounts of food then originally intended, as well as having a reduced ability to participate in a range of social and occupational activities. They also make frequent and usually unsuccessful attempts in controlling their overconsumption of food, and/or continue their overeating while ignoring the consequences to their health. This striking likeness to characteristics of substance dependence has prompted the proposal of obesity to be included in the Diagnostic and Statistical Manual of Mental Disorder (DSM).

Consumption of food, other than eating from hunger, and some drug use are initially driven by their rewarding properties, which in both instances involves activation of mesolimbic dopamine (DA) pathways (Volkow, Wang, Fowler & Telang F, 2008). As a result, they both activate identical brain structures which involve reward processing, motivation, decision-making, learning, and memory. When the DA pathways are consistently stimulated, it will trigger activity in other transmitter systems, which will result in increased compulsive behaviour as well as in a loss of control over food and substance intake. Correspondingly, repeated exposure to foods with high fat and sugar content results in compulsive food consumption, poor control of food intake, and food stimuli conditioning (Voon et al, 2009).

In this section, four of the main circuits will be covered, which are reward/saliency, motivation/drive, learning/conditioning, and inhibitory control/emotional regulation/executive function.

The reward/saliency circuit modulates our response to positive and negative reinforcers (Volkow, Wang, Fowler, Tomasi, & Baler, 2012). When there is a dysfunction in the circuitry, individuals tend to undervalue stimuli, which might motivate good behaviour while ignoring the negative consequences that stem from bad ones. In the case of obesity, the person would be less likely to be motivated to abstain from eating because alternative reinforcers (physical activity and social interactions) are less exciting and negative consequences (e.g. gaining weight, diabetes) are less salient (Weltens, Zhao, & Van Oudenhove, 2014).

If the inhibitory control/emotional regulation circuit is disrupted, the ability to inhibit intense desires, such as the want of drugs by an addicted subject, or the desire for high-density food in obese individuals, are impaired (Loeber et al., 2012). As a result, the person is less likely to succeed in inhibiting the intentional actions and to regulate the emotional reactions associated with the strong desires.

As for the circuit involving learning/conditioning, the repeated use of drugs or consumption of huge quantities of high-density food (obese individual) results in the formation of new linked memories, which condition the individual to expect pleasurable responses (Volkow, Wang, Tomasi & Baler, 2013). When this circuit is affected, the person will expect pleasurable responses not just from direct stimulus, but also from stimuli conditioned to the food or drug. These stimuli trigger automatic responses that frequently drive relapse in the drug abuser/addict and food bingeing, even in those who are motivated to stop taking drugs or to lose weight.

The motivation/drive and action circuit both executes and inhibits the act of pursuing the stimulus, be it drug or food. Its actions are also dependent on the information from the reward/saliency, memory/conditioning and inhibitory control/emotional reactivity circuits (Wang, Volkow, & Fowler, 2002). When the value of a reward is enhanced owing to its previous conditioning, it has greater incentive motivation and if this occurs in parallel to a disruption of the inhibitory control circuit this could trigger the behaviour in a reflexive fashion. This therefore explains why obese individuals find it difficult to control their food intake as well as why they eat compulsively, despite claims that they no longer perceived food as pleasurable.

While the many suggestions as to how food addiction comes about are very convincing, there are still inconsistencies in the evidence of human studies that the food addiction model should not be accepted as valid yet (Ziauddeen & Fletcher, 2013). The preliminary evidence suggests that more research needs to be carried out before coming to a conclusion regarding its legitimacy.

1.5.4 Impulsivity/Binge-eating Disorder

Impulsivity is a multidimensional personality trait which contributes to the development and maintenance of obesity as it causes uncontrolled and excessive food intake (Kulendran et al., 2013). Binge-eating disorder has also been associated with impulsivity, due to its defining characteristic, experiencing loss of control while consuming a large amount of food (Brauhardt, Rudolph & Hilbert, 2014). Impulsivity is a multifaceted construct and have been tested using different scales and models. According to Whiteside and Lynam (2001), it consists of 4 facets, which are: urgency, defined as 'the tendency to experience strong impulses, frequently under conditions of negative affect'; lack of perseverance, defined as 'the difficulty to remain focused on a task that may be boring or difficult'; lack of premeditation, defined as 'the difficulty to think and reflect on the consequences of an act before engaging in the act'; and sensation seeking, defined as 'a tendency to enjoy and pursue activities that are exciting, and openness for new experiences' (Mobbs, Crépin, Thiéry, Golay & Van der Linden, 2010). It is suggested that obese and overweight persons find it difficult to inhibit automatic or dominant behaviours and intrusive thoughts. They also have a tendency to exaggerate the impact of rewards and punishments. As these traits involve dimensions of impulsivity, it is evident that there might be a link between impulsivity and food intake.

Impulsivity and Binge Eating Disorder (BED) are also found to be correlated to food addiction (van den Berg et al., 2011). In a study, the food addiction construct was further tested by the YFAS (Yale Food-addiction Scale). Binge eating and food addiction are found to have similar overlapping characteristics. The UPPS Impulsive Behaviour Scale was used to measure impulsivity, based on the five factor model of personality. The facets were negative urgency, sensation seeking, and a lack of premeditation and perseverance. At the end of the study, it was found that lack of perseverance and negative urgency had direct link to addiction and an indirect link to BMI.

On the other hand, the Barrett Impulsivity Scale (BIS) separates impulsivity into three distinct types: attentional impulsivity (inability to focus attention or concentrate), motor impulsivity (acting without thinking) and non-planning impulsivity (lack of future orientation or forethought) (Fields, Sabet & Reynolds, 2013). In another study involving the BIS, it appears that attentional impulsivity is most consistently related to various measures that are associated with overeating. Positive, but less consistent, relationships can also be found with motor impulsivity, particularly in patients with binge eating behaviour. Non-planning impulsivity seems to be only weakly related to overeating. Neither subscale seems to be consistently correlated with BMI, which may be due to the fact that BMI is influenced by many factors other than eating behaviour (Murphy, Stojek, & MacKillop, 2014).

In addition, impulsivity is also linked to different maladaptive eating styles which cause obesity (Banos et. al., 2014). Emotional eating refers to eating in response to negative emotions (e.g., anxiety or irritability) and it has been studied in relation to eating binges in Bulimia (BN) and Binge Eating Disorders (BED) (Lo Coco, Salerno, Bruno, Caltabiano, & Ricciardelli, 2014). By contrast, external eating refers to eating in response to external food-related cues (e.g., the reinforcing value of the sight and smell of attractive food) regardless of internal signals of hunger and satiety, as a result of an elevated responsiveness to food-related cues in the immediate environment. External eating has been found to be a relevant style in obesity and a predictor of food cravings. However, its association with weight gain is less clear and research findings also suggest that responsiveness to food cues may be a general adaptive characteristic that is not exclusive to overweight people. Finally, restrained eating involves eating less than desired in order to lose or maintain one's body weight. "Restraint theory" states that eating behaviour is affected by a balance of forces, including physiological pressure to eat and a non-physiological self-imposed resistance (i.e. restrained eating) to this pressure. Dietary restraint has been associated with reduced food intake (reduction of total and saturated fat intake), although positive correlations have also been found with weight gain.

From a recent study by Banos and colleagues (2009), there was greater incidence of emotional eating in obesity only, while more restrained eating was prevalent in both AN and Obesity. Reward sensitivity, which is linked to impulsivity, is also known to interact with the food environment, and induces greater desire for food consumption in the presence of more food variety (Guerrieri, Nederkoorn & Jansen, 2008). The fact that unsuccessful response inhibition is linked to becoming overweight, but not to food intake, could indicate that it is a mechanism that kicks in later in the process of becoming overweight or obese.

Chapter 2 How is Impulsivity defined?

Impulsivity is a construct that is both complex and multidimensional (Evenden, 1999). The International Society for Research on Impulsivity defines impulsivity as '*behaviour without adequate thought, the tendency to act with less forethought than do most individuals of equal ability and knowledge or a predisposition towards rapid, unplanned reactions to internal or external stimulus without regard to the negative consequences of these reactions'*. (International Society for Research on Impulsivity, 2013). The Oxford dictionary also defines impulsivity as an almost automatic behaviour pattern: '*acting or doing without forethought or the inclination to act on impulse rather than thought'*. Therefore, impulsivity can be thought of as a mechanism of behavioural control fundamental to psychological explanation of behaviour patterns. The individual difference in these mechanisms may be assumed to play an important role in the psychological basis underpinning personality (Johnson & Joorman, 2008). In cognitive psychology the 'dual process model' conceptualises attention and working memory to rely on two distinct processes leading to observed behaviour (Barrett, Tugade & Engle, 2004). The dual process model describes both an automatic (or reflexive) and controlled (or reflective) decision making pathways (Metcalfe & Mischel, 1999). (Table 2-1). Automatic decisions are subconscious and often based on heuristics. On the basis of sizeable body of animal and human behavioural and neurobiological evidence, recent integrative approaches to decision making in cognitive neuroscience and integrative theories of motivation in health psychology have distinguished two distinct systems for automatic behavioural control (Anderson et al., 2004; West, 2006). The first system which is of interest to us is the impulsive motivation systems, which is based on an evolutionary acquired affective response (e.g. disgust, greed, attraction) to specific environmental stimulus (e.g. food, money, social groups) (Fiske, 2010) and assigns value to only a small set of prepared behaviours (e.g., approach, avoidance, consumption, defensive and fighting responses) (Anderson et al., 2004). The second, habit systems, is centred on learning through repeated practice in a stable environment, to flexibly assign values to a variety of adaptive motor actions and mental operations (e.g., heuristics; Gigerenzer & Goldstein, 1996; Verplanken, Friborg, Wang, Trafimow, & Woolf, 2007; Wood & Neal, 2007). The remainder of this chapter shall focus on impulsivity, which is the concept on which the automatics process system is based (Table 2.1).

Table 2.1 The difference between automatic and controlled behaviours. Impulsive actions are part of the automatic behavioural pathway.

Automatic	**Reflective**
Fast	Slow
Coarse grained	Fine grained
Ballistic (implicit procedural learning)	Deliberate (explicit/declarative learning)
Pre/non-conscious	Accessible to conscious awareness

Impulsivity is a multifactorial construct as supported by a poor correlation between commonly used measures and pharmacological studies (Buss & Plomin, 1975; Evenden, 1998). Figure 2.1 lists some of the more popular definitions from the literature. Most of these definitions are based on a theory often supported by component analysis of personality questionnaires.

Figure 2-1 Common definitions of impulsivity from the personality literature

> *'Characterised by inclination initiate behaviour without adequate forethought as to the consequences of their actions. Acting on the spur of the moment.'* (Barratt & Patton, 1983)
>
> *'Impulsion: a sudden urge to act in response to subjective or external stimuli: used especially of behaviour viewed as powerfully motivated, compulsive or irrational.'*
>
> *'Risk taking, lack of planning, making ones mind quickly. They act without considering consequences.'* (H. J. Eysenck & Eysenck, 1977a)
>
> *Lack of planning, lack of focus on the task in hand and the tendency to act without delay.'*(Patton, Stanford, & Barratt, 1995)

The definition of impulsivity varies based on the context in which it is being used (Figure 2-1). Impulsivity is traditionally thought to be one of many potential traits used to describe personality. Personality traits are habitual patterns of behaviour, thoughts and emotions, which characterize an individual (Kassin, 2003). Impulsivity has been described both in healthy subjects and those with pathological conditions. The pathological conditions include personality disorders, ADHD and addiction. Before exploring the role of impulsivity in pathological states, the fundamental theories of impulsivity are described. Accompanied by the description is a brief analysis of the questionnaire upon which the theory is based.

2.1 Theories of Impulsivity

2.1.1 Dickman's model of impulsivity: Functional versus dysfunctional.

Dickman was the first to describe impulsivity as being functional or dysfunctional (Dickman, 1990). Dickman's definition of impulsivity is 'the tendency to deliberate less than most people of equal ability before taking action'. Dysfunctional behaviours are those in which the individual has the tendency to act with less forethought, resulting in negative consequences. Functional impulsivity, on the other hand, has positive consequences such a quick adaptive responses in emergent situations. This two dimensional theory is based on an information processing approach to personality in which cognitive processing and intellect are likely to play a major role in the behavioural outcome. Dysfunctional impulsivity is thought to be associated with disorderliness, a tendency to ignore hard facts when making decisions, acting without forethought, and a tendency to engage in rapid, error prone information processing because of an inability to use a slower, more methodological approach under certain circumstances. Functional impulsivity is associated with enthusiasm, adventuresomeness, level of activity and ability 'to engage in rapid error prone information processing when such a strategy is rendered optimal by the individual's other personality traits. Dickman also identified, but rejected, two other key facet of impulsivity in common use today: reflection-impulsivity and the syndrome of inhibition (Dickman, 1990). Dickman also point out a key theory concerning cognition in the role of impulsive behaviour. In what he describes as attentional impulsivity despite less forethought before an action, he noted that individuals who scored as being more impulsive responded more slowly in experimental tasks than non-impulsive individuals. From this finding he postulated that impulsive individuals spend less of the response time focusing on the task in hand and they may be suited to tasks, which require attention to be switched rapidly.

2.1.1.1 Dickman Impulsivity Inventory (DII)

The functional impulsivity scale contains the items that involve the use of fast response style in solving social and cognitive problems when the consequences of this approach are positive (I am good at taking advantage of unexpected opportunities, where you have to do something immediately or lose your chance' or 'People have admired me because I can think quickly'). On the other hand, the dysfunctional impulsivity scale involves classical impulsivity items where individuals report acting without thinking and the problems this style brings (I will often say whatever comes into my head without thinking first' or ' Often I do not spend enough time thinking over the situation before I act'). The two scales show low positive or a lack of correlation (Claes, Vertommen & Braspenning, 2000; Dickman, 1990). The DII is a 23-item inventory answered using a true/false format (11 items for DII-F and 12 items for DII-D). Both subscales appear to have good psychometric properties. Dickman (1990) reported internal reliability coefficients for the dysfunctional scale as 0.85 and for the functional subscale 0.74. The DII shows good construct validity against other self-report and behavioural measures of impulsivity.

2.1.1.2 Dickman's Inventory and Obesity

The Dickman Inventory was unable to differentiate between high and low restraint and disinhibited participants as measured by the Three Factor Eating Questionnaire (Yeomnas, Leith & Mobini, 2008). There is no other record of work related to impulsivity using Dickman's Inventory.

2.1.2 Eysenck and Eysenck

Eysenck (1968) postulate three dimensions of personality: Extraversion, Psychotism and Neuroticism based on self-report questionnaires. Initially, impulsivity was a sub-scale of the first order personality trait extraversion. Extraverts can be described as being sociable and active. The original concept of extraversion was linked to arousal (Eysenck, 1967). Extroverts were thought to have lower cortical arousal and hence were unable to readily condition to their environment, therefore having difficulty socialising and being less sensitive to social constraints.

The personality trait was further revised which included liveliness and sociability under extraversion, but excluded impulsivity (Rocklin & Revelle, 1981). Impulsivity was placed into four broad categories: narrow impulsiveness, risk taking, non-planning and liveliness (Eysenck & Eysenck, 1977b). Testing found that these four impulsivity scales correlated differently with extraversion, neuroticism and psychotism. Narrow impulsiveness had a high correlation with neuroticism and psychotism but no longer correlated with extraversion. These findings led to a reconsideration of the original three factor theory. Eysenck developed a further questionnaire the I_5 (Eysenck, 1993) that identified two factors labelled as impulsiveness and venturesomeness. Venturesomeness is defined as 'risk-taking behaviour, knowing fully there is a risk involved' and is related to extraversion from the original scale and impulsiveness which is 'a complete lack of looking ahead at the consequences of one's actions' and was related to Psychotism. Psychoticism is the third and least well defined dimension of Eysenck's model. Individuals who score high on this scale are strong minded and non-conformist. Eysenck (1993) has also been influential in the theory base for impulsivity by postulating extraversion and by extension impulsivity is caused by low cortical arousal. It is important to note that cognitive and motor impulsivity (related to hyperactivity) are independent dimensions, as evaluated by Eysenck's Personality Questionnaire.

2.1.2.1 Adult Impulsiveness scale I7 by Eysenck

The I7 Adult Impulsiveness Questionnaire was published in 1985 (Eysenck et al. 1985). The I7 is a self-report scale, which assesses two dimensions of impulsivity: Impulsiveness and Venturesomeness. Eysenck and colleagues (1985) define impulsiveness as 'behaving without thinking and without realising the risk involved in the behaviour'. Venturesomeness is described as 'being conscious of the risk of the behaviour but acting anyway'. The questionnaire consists of 54 items answered as true or false. The impulsiveness subscale contains 19 items (e.g. "Do you often do things on the spur of the moment?"), whilst 16 items make up the Venturesomeness subscale (e.g., "Do you sometimes like doing things that are a bit frightening?"). The remaining 19 items make up the empathy subscale. Eysenck and colleagues (1985) report good reliabilities for the three subscales. Test-retest reliabilities were 0.78 and 0.9 for men and women on the Venturesomeness and Impulsiveness scale.

2.1.2.2 Eysenck Personality Questionnaire (EPQ) and Obesity

Children with severe obesity (greater than 50% overweight) have been found to have significantly higher EPQ psychotism score (Li, 1995). In adults the EPQ showed that obese men showed significantly lower extraversion scores in comparison to average weight adults (Abraham, 2012). This difference was attributed to obese individuals not socialising with others due to their body stature. Similarly, Faith and colleagues (2001) found that a higher BMI in females was significantly associated with higher levels of neuroticism, but lower levels of extraversion as measured by EPQ. This finding did not hold true for the male subjects. In males, a higher BMI was associated with a greater level of extraversion. In contrast, Hallestrom, Noppa and colleagues (2001) found significantly higher extraversion scores using the EPQ in women who were obese when age and socioeconomic status were taken into account. Segraves (1970) found neutroticism and extraversion to be significantly related to body size and found the neurotic subjects were often small and extraversion was correlated with wide physique. Kittel and colleagues (1977) found obese male subjects to be more extraverted and less neurotic than non-obese male subjects. Korkeila and colleagues (1998) found that for older females (between 30 and 54), high levels of neuroticism were associated with a great BMI at the beginning of the study. However, there was no such association between BMI and extraversion. In males, high self-reported measures of extraversion were a predictor of lesser weight gain.

2.1.3 Gray's Neuropsychological Theory

Gray proposed the neuropsychological theory of personality, in 1970, based on extensive animal research (Larsen & Buss, 2009), that identified two dimensions of personality: impulsivity and anxiety. Gray's model (1981) is closely related to Eysenck's original model of personality where impulsivity is related to Extraversion and anxiety is related to Neuroticism. Unlike Eysenck, Gray believed that personality traits and disorders could not be explained by classical conditioning alone. This theory highlighted the relationship between personality and sensitivity to reinforcement (i.e. reward and punishment) through two individual mechanisms: the appetitive behavioural approach system (BAS), associated with trait impulsivity and an avoidant behavioural inhibition system (BIS) which controls anxiety. The BAS includes brain regions involved in regulating arousal: cerebral cortex, thalamus, and striatum. The system is responsive to conditioned and unconditioned reward cues. BAS regulates approach behaviours and is referred to as the reward system. The BAS has a broad affective quality, making those with BAS sensitivity more likely to experience happiness and hope and therefore engage more in goal directed efforts, whilst the BIS system responds to signals of punishment and novel stimulus.

2.1.3.1 The BIS/BAS Scales

Carver and White (1994) developed the BIS/BAS scale to provide a self-report measure of Gray's theory of personality (Gray, 1972, 1981). The BIS/BAS is a 24 item questionnaire in which participants respond on a 4 point likert scale, indicating their level of agreement with a given statement. The BAS is composed of three subscales: Drive (4 items, e.g. "I go out of my way to get things that I want"), Fun-seeking (4 items, e.g. “I crave excitement and new sensations”) and Reward Responsiveness (5 items, e.g. “When I am doing well at something I love to keep at it”). The three subscales of the BIS/BAS have been reported to have good internal reliability (Carver and White, 1994; Jorm et al., 1999; Ross et al., 2002). However, factor analytic studies replicating the four factor structure and two distinct scales (BIS/BAS) have produced a model of fit with low significance (Heubeck, Wilkinson and Cologon, 1998) and questioned the validity of the reward responsiveness scale (Ross, Millis, Bonebright and Bailley, 2002).

2.1.3.2 BIS/BAS Scale and Obesity

Davis and colleagues collected self-reported data on sensitivity to reward using the BAS subscale of the BIS/BAS scales. Tests were conducted to determine whether sensitivity to reward could lead to overeating and food preferences for sweet and fatty foods leading to weight gain (Davis, Strachan & Berkson, 2004; Davis et al., 2007). Using structural equation modelling sensitivity to reward was linked positively to overeating and preferences for food high in sugar and fat and overeating and food preferences were in turn linked to positively to BMI. Patients with Anorexia Nervosa and Bulimia Nervosa are characterised by overeating or binge eating. Patients with eating disorders have been differentiated from control groups on scores of attentional impulsiveness but could not be differentiated by scores on the BIS/BAS (Rosval et al., 2006). Binge eating disorder (BED) is another commonly encountered eating disorder. Obese women with BED have been shown to score lower on the BAS reward responsiveness and fun seeking subscales, and there were no difference between the groups as measured by the BIS subscale. Therefore, there are mixed findings in this subject area (Svaldi, Brand & Tuschen-Caffier, 2010). Nederkoorn and colleagues (2004) found that healthy women who scored high on the restraint scale which is often associated with unsuccessful dieting also scored higher on the BIS/BAS impulsivity subscales. Nederkoorn and colleagues (2006) found no difference between obese and normal weight adolescents using the subscale. The Sensitivity to Punishment and Sensitivity to Reward Questionnaire for children (SPSRQ-C) is a modification of the BIS/BAS. Van den Berg and colleagues (2011) using the SPSRQ-C showed that obese adolescents scored significantly higher than normal weight and lean counterparts in both the BIS and BAS subscales, by univariate analysis. The authors used an overeating questionnaire and by means of a mediation analysis concluded that both BIS (impulsivity and fun seeking) and BAS (reward responsiveness) scores influenced BMI through overeating. In addition to eating behaviour, the BIS has been strongly associated with fitness-related exercise behaviour (Schneider & Graham, 2009). Functional imaging studies have shown that BAS scores significantly predicted activation to appetizing relative to bland foods in brain regions implicated in reward such as the right ventral striatum, left amygdala, substantia nigra and ventral tegmental area of the midbrain (Beaver, Lawrence, Ditzhuijzen, Davis, Woods & Calder, 2006).

2.1.4 Five Factor Model

The Five Factor Theory of personality was first introduced by McCrae and Costa (1985) and is based on the assumption that personality is relatively stable in adulthood. It is a hierarchical organization of personality traits in terms of five basic dimensions: Extraversion, Agreeableness, Conscientiousness, Neuroticism and

Openness to Experience. Factors were named using both lexical statements (studying trait language) and questionnaire-based methods. Each of the five broad higher-order factors is composed of six sub factors called facet. Within this model there appears to be four distinct facets, on three different domains, that capture some aspect of impulsivity. Costa and McCrae (1992) explicitly propose that low self-control is measured by the impulsiveness facet of the Neuroticism domain and by the self-discipline facet of Conscientiousness domain of the personality inventory and the revised NEO Personality Inventory (NEO-PI-R). Specifically they assert that 'people high in impulsiveness cannot resist doing what they do not want themselves to do' and that people low in self-discipline cannot force themselves to do what they want themselves to do'. High scores on the Impulsiveness facet are described as lazy, disorganized and not thorough. In addition, there are two other facets, which are also invariably captured by other authors. The first is the excitement-seeking facet of extraversion that is similar to the dimension of sensation seeking of Questionnaire name (Zuckerman, 1971) and the venturesomeness of Eysenck and Eysenck (S. B. Eysenck & Eysenck, 1977b); high scorers on this facet are described as pleasure seeking, daring and adventurous. Second, there is the deliberation facet of Conscientiousness, which is similar to Tellegen's control scale to Barrat's non-planning factor; low scorers on this facet are described as hasty, impulsive, careless and impatient. The five factor model does not capture some domains of personality relevant to personality disorders, such as individual autonomy, traditional moral values, and other aspects of maturity and self-conceptualisation described in humanistic and transpersonal psychology (John, 1990).

2.1.4.1 The Revised NEO Personality Inventory

The Revised NEO Personality Inventory is a 240-item measure of the five factor model of personality traits. Extraversion, Agreeableness, Conscientiousness, Neuroticism and Openness to Experience are its scales. The questionnaire also measures six subordinate dimensions (facets of the Five Factor Model. The internal consistency of the NEO is high: Neuroticism (0.92), Extraversion (0.89), Openness (0.87), Agreeableness (0.86) and Conscientiousness (0.83). The retest reliability is also good as six years being: Neuroticism (0.83), Extraversion (0.82), Openness (0.83), Agreeableness (0.63) and Conscientiousness (0.79)(Sherry, Hewitt, Flett, Lee-Baggley, & Hall, 2007).

2.1.4.2 NEO Personality Inventory and Obesity

Traits within the Five-Factor Model of personality have been linked to abnormal weight (Brummett et al., 2006; Chapman, Fiscella, Duberstein, Coletta & Kawachi, 2009; Terracciano et al, 2009). In a large longitudinal study (N=1,988) over a 50-year period in which the trajectory of BMI was modelled and personality was examined as a predictor for change, it was found that participants higher in neuroticism or extraversion or lower in conscientiousness had a higher BMI. The strongest association was found for the impulsivity facet (N5: impulsiveness). Partcipants who scored in the top 10% of impulsivity weighed on average 11kg more than those in the bottom 10%. Longitudinally, those who were highly impulsive and prone to depression were prone to fluctuations in their weight over time. The emotional aspects of impulsivity (N5: Impulsiveness and E5: excitement seeking) were all associated with greater increase in adiposity. As an example, at age 30, those who scored one standard deviation above the mean on impulsivity had a BMI that was approximately 2.30 points higher than those who scored one standard deviation below the mean on this trait. By the age of 90, this gap increased to a 5.22 BMI point difference (Sutin, Ferrucci, Zonderman & Terracciano, 2011).

2.1.5 Four Factor Model

Whiteside and Lynam (2001) identified facets of impulsivity that are common across instruments and placed them in a broad model of personality. The Five-Factor Model of personality (McCrae & Costa, 1990) was used to provide a framework from which the new theory was conceptualised. The new four factor model hypothesised that the FFM contained four distinct traits (impulsiveness, excitement seeking, self discipline and deliberation) that were different pathways to impulsive behaviour. Whiteside and Lynam (2001) factor analysed nine frequently used measures of impulsivity in a sample of 436 undergraduates and identified four discrete factors. These make up the UPPS Impulsivity Scale, which has four subscales: Urgency, lack of Premeditation, lack of Perserverance and Sensation Seeking.

2.1.5.1 The UPPS Impulsivity Scale

The first factor, Urgency, refers to the tendency to engage in impulsive behaviours under conditions of negative affect despite the potentially harmful long term consequences. Subjects with higher scorers have difficulty resisting craving and temptations leading to eating problems (J. Miller, Flory, Lynam, & Leukefeld, 2003). The UPPS assesses impulsivity on the subscales urgency (acting rashly under conditions of negative affect), lack of premeditation (difficulty in thinking and reflecting on consequences of an act), lack of perseverance (inability to remain focus on a task) and sensation seeking (tendency to and openness to try and enjoy exciting or dangerous activities). Subscales have evidenced good reliability: Urgency (0.89), lack of Premeditaion (0.87), lack of Perseverance (0.83), and Sensation seeking (0.85) (J. Miller et al., 2003).

2.1.5.2 UPPS and Obesity

The UPPS questionnaire is able to distinguish between obese and normal weight participants. Overweight and obese persons have a higher level of Urgency, Lack of Perseverance and Sensitivty to Reward (Mobbs, Crepin, Thiery, Golay & Van der Linden, 2010). A cross-sectional study of 233 adult participants found impulsivity to be directly associated with BMI by way of associations with addictive consumption of food. Using a bootstrapping approach which looked at indirect associations and inclination towards behaving irrationally while experiencing negative mood states (Negative Urgency) and low levels of task persistence (lack of perseverance) were significantly associated with food addiction directly and that relationship was responsible for their relationship to BMI (Murphy, Stojek & MacKillop, 2014).

2.1.6 Ego or Cognitive Depletion

Ego depletion is an important concept in experimental psychology and is based on the ‘energy model of self-control’ (Hagger, Wood, Stiff, & Chatzisarantis, 2010). It states that an individual has a definitive mental pool of resources in order to maintain self-control. Self-control is what allows one to pursue long-term goals and it is based on ideals, morals, values and social expectations (Baumeister, Vohs, & Tice, 2007). Acts of self-control uses up the existing mental reserve leaving an individual more vulnerable to impulsive acts due to a reduced capacity for self-regulation (Baumeister, 1998). Ego depletion is compared to muscle fatigue and could result from either an act of great self-control or temporal depletion by multiple small acts over time (Muraven & Baumeister, 2000). This is termed the strength model of self-control. It is believed that efforts to control behaviour in one domain of life such as spending money or performing regular exercise leads to an improvement in other unrelated domains such as studying or household chores. Also, daily exercises in self-control such as improving posture, and altering verbal behaviour improve self-control as measured by laboratory tasks. The broad trans-domain improvement in self-control supports the notion that these improvements are not solely due to increasing skill levels.

2.1.7 Barratt's Model

Barratt (1993) uses information from four diverse perspectives in his model: the medical model, psychological model, behavioural model and social model. The tridimensional model of impulsivity focuses on three concepts: attentional impulsiveness which is the inability to maintain attention to tasks or cognitive instability, motor impulsiveness which involves acting without thinking (on the spur of the moment) and finally non-planning impulsivity which is the lack of futuring or forethought (Barratt, 1985). Barratt modelled the various aspects of impulsivity as part of a general action orientation (Barratt & Patton, 1983). Much of the thought processes underpinning the making of Barratt's model of impulsivity is lacking due to a much unpublished psychometric data.

2.1.7.1 Barratt's Impulsivity Scale (BIS)

The BIS was initially developed to separate impulsivity from anxiety. It was later refined to identify impulsivity from other action-orientated traits such as sensation seeking, extraversion and risk taking (Monahan, 1996). The BIS in all its forms is the most commonly administered self-report questionnaire in research and in the clinical setting. The subtraits of the BIS have been derived from measures of self-report questionnaires, cognitive and behavioural tasks and brain-behavioural research in animals (Barratt, 1993).

Barratt initials described three components of impulsivity assessed by the BIS-10 in 1985. Patton (1995) developed the BIS-11 by a primary component analysis of the BIS-10 given to 412 university students. It produced 6 first order factors: attention, motor, self-control, cognitive complexity, perseverance, and cognitive instability. These first order factors correlated well with the sub-traits of motor impulsiveness (motor and perseverance) and non-planning impulsiveness (self-control and cognitive impulsivity). It was, however, difficult to identify the components of the cognitive impulsiveness sub-trait. Hence it was labelled attentional impulsiveness, which is composed of the first order factors attention, cognitive instability and defined as the inability to focus or concentrate. The BIS will be discussed further in the Methodology chapter.

2.1.7.2 Barratt Impulsivity Scale and Obesity

Clinical samples with eating disorder have been shown a differential relationship between with various subscales of the BIS eating disorder symptomatology. Patients with BED have higher scores on the motor impulsivity subscale compared to healthy controls but do not differ on the other two subscales (Nasser, 2004). Two studies have compared scores on the BIS between patients with BN, AN (both binge-purge type and restrictive type) and healthy controls (Rosval et al., 2006; Claes et al., 2006). People with binge eating behaviour have higher BIS scores, particularly on its motor and attentional impulsivity subscales, compared to people with restrictive eating behaviour and controls.

2.1.8 Cloninger's Biosocial Model of Impulsivity

Clonginger's biosocial theory of personality is the most proclaimed construct theory in psychiatry (Cloninger, 1987). Cloninger disputed Eysenck's model that with regard to personality phenotypic and genotypic structures are the same. He argued that genetic and environmental influences do not influence behaviour in the same way. He also noted that the rate of operant learning in response to signals of reward was maximal along the impulsivity dimension, not Eysenck's extraversion factor. Cloninger (1987) describes three genetically independent dimensions of personality: Novelty Seeking, Harm Avoidance and Reward Dependence and the more recently added Persistence (Table 2-2). Each dimension has been postulated to be associated with a neurotransmitter system and highly reliable and stable in both normal and abnormal samples (Cloninger, Przybeck, & Svrakic, 1991). For example, the Novelty

Seeking is thought to relate activation in the dopaminergic reward system. There is no single factor in the questionnaire, which corresponds with impulsivity. However statements, which siphon impulsive characteristics, are dispersed through out the three personality dimensions. High Novelty Seeking, for example, includes 'acts immediately on momentary whims' or 'extravagant spending so has difficulty saving or delay gratification'. Novelty Seeking is hypothesised to be a heritable tendency towards intense exhilaration or excitement in response to novel stimuli or cues for potential rewards or potential relief of punishment, which leads to frequent exploratory activity in pursuit of potential rewards as well as active avoidance of monotony and potential punishment. Genetic variation each dimension is thought to follow normal distribution with most people having intermediate values.

Table 2-2 A Table illustrating the components of the Novelty Seeking Scale of the TCI

Summary of Novelty Seeking Scale	
+3	Severely High: Consistently seeks thrilling adventures and exploration; disorderly and unpredictable; intolerant of structure and monotomy regardless of consequences; decisions and opinions based on vague global impressions and intuitions; consistently plays roles for dramatic effect so the real feelings and beliefs are uncertain; consistently spends on impulse in absence of external constraints; interests and friendships shift rapidly with the latest influence without any sustained commitments.
+2	Moderately High: Usually seeks exhilaration from thrilling ventures and exploration of unfamiliar places and situations; intolerant of structure and routine, trying to break rules and introduce change; easily excitable and quick tempered and engaged with new ideas, activities, or people; strongly prefers to act on intuitive and frequently has to revise these decisions; skilled and convincing at role playing and dramatic exaggeration; prefers impulse spending but able to save for special occasions.
+1	Mildly High: Prefers pursuits of exciting thrills and exploration to familiar routines unless benefits from stable routines are highly likely; tolerates structure and discipline without much sdifficulty; more excitable and easily engaged than average and more easily becomes disinterested and bored by monotomy; prefers quick decisions based on hunches and impressions rather than detailed analysis; mildly histrionic and convincing in dramatic role playing; prefers to spend on impulse withough a budget but responsibly avoids major debt.
0	Equally tolerant of novelty and routine with choices depending on what appears more beneficial; balanced use of both logical analysis and intuition; average amount of role playing and attention to saving; average excitability and rate of engagement/disengagement with people, activities, or ideas.
-1	Mildly Low: Prefers to stay with familiar routines unless benefits from new ventures are highly likely; orderly and well organised but does not ususally try to impose stable structures; slower to become excited or attached than average; enjoys thrill and novelty when encountered but does not seek them out; usually prefers logical analysis over intuitive

	hunches but also acts on first impressions; limited role playing or dramatic exaggeration but will often lie or disguise feelings to spare others' feelings; prefers to save and budget but not obviously stingy or frugal.
-2	Moderately Low: Prefers to stay with familiar routines unless benefits from new ventures are nearly certain; orderly and disciplines, usually trying to impose stable structure and organisation; reserved and controlled, slowly becomes excited, angry, or enthusiastic or interested and attached; prefers detailed analysis over quick intuitive impressions but sometimes uses impressions tentatively; limited role playing and dramatic exaggeration; strong preference for saving and spending according to budgets over impulse spending.
-3	Severely Low: Resists nearly all attempts to modify familiar routines; disinterested in novelty and exploratory pursuits regardless of potential benefits; highly orderly and well organised, trying to impose stable structure and consistent routine; highly controlled, rarely becoming angry or excited quickly; analytical decision maker who always requires detailed analysis of complete information, consistently direct and honest without role playing or exaggeration; highly frugal with consistent effort to save and budget; loyal and stoical, highly slow to form and change interests and social attachment.

2.1.8.1 Cloninger's Temperament and Character Inventory (TCI)

Cloninger's dimensions are assessed by the 240-item self-report questionnaire (Cloninger, 1999). Cloninger's Temperament and Character Inventory is discussed fully in the Methodology chapter.

2.1.8.2 TCI and obesity

Cloninger showed the Temperament and Character Inventory to be a predictor of weight reduction. In participants who attended a community lifestyle intervention those who scored highly on the Novelty Seeking scale were found to lose less weight post intervention (Sullivan, Cloninger, Przybeck, & Klein, 2007). Pre-surgical TCI Persistence scores on the other hand explained >40% of variance of BMI reduction at one follow up after gastric band surgery (Panfilis et al., 2006). Similar findings have been found in those undergoing gastric by-pass surgery (Panfilis, Generali, Dall'Aglio, Marchesi, Ossola & Marchesi, 2014). Fassino (2002) compared obese participants with and without BED against normal weight participants. Obese participants regardless of their binge eating status differed significantly from controls in Novelty Seeking and Harm Avoidance (HA). A high score in HA is a temperament trait also exhibited in patients with BN and AN (Klump et al., 2000; Bulik, Sullivan, Weltzin & Kaye, 1995). The Harm Avoidance system, in particular, is associated with alterations in the serotonin brain system (Cloninger, & Svrkic, 1999). The obese binge eaters varied from obese non-binge eaters only with regard to character, having a lower self transcendence. This character trait was also predictive of weight gain in those with binge eating behaviour. Attempts to characterise participants with BED into clusters by their performance on the TCI identified two separate groups of patients diagnosed with BED (Leombruni et al., 2014). Those described as being Cluster 1 had a higher educational attainment, and desire to have a body weight significantly lower than that desired by Cluster 2. Cluster 1 participants reported greater psychological distress about their body shape and had higher psychopathology scores both in mood and in the degree of loss of control over eating. Those in Cluster 1 had a notably higher HA and lower SD than Cluster 2. Begin and colleagues (2012) also compared females who were diagnosed as having a food addiction using the Yale Food Addiction Questionnaire, those with substance use disorder and women seeking treatment for compulsive over eating.

However, only the self-directedness scale was able to distinguish between groups, with those seeking treatment scoring highest of all the groups. Villarejo and colleagues (2012) showed that in 1383 female with an eating disorder were assessed for their life time prevelance of obesity. Compared to eating disorder patients without a lifetime of obesity, participants with a lifetime of obesity had higher scores of Harm Avoidance, lower traits of Persistence, self-directedness and co-operativeness. In a comparison of obese adults to normal weight Spanish adults, the obese group were found to show higher scores in Harm Avoidance but lower scores in Novelty Seeking, Persistence and self-transcendence (Lopez-Pantoja et al. 2012). For example high scores in harm avoidance implies that obese individuals cannot tolerate aversive experiences such as when not satisfying ones desires for eating (which may lead to feelings of frustration) or physical activity, which many obese people may find unpleasant.

2.2 Behavioural Measures of Impulsivity

So far we have discussed the personality measures of impulsivity with their corresponding model. However, impulsivity is also a commonly applied behavioural construct, which has been used to better our understanding of eating behaviour and obesity. Behavioural measures are laboratory tests that provide a method to study underlying brain mechanisms related to impulsivity. In the field of neuropsychology, behavioural measures are thought to capture different facets of impulsivity to personality questionnaires and can complement ones understanding of behaviour or possibly confirm finding from each other. For example, a commonly studies concept in eating behaviour is self-control. Neurobiological studies have begun to form neurobiological substrates of this construct. A behavioural measure of this construct may be performance on the stop signal task (discussed below) and a questionnaire based measure of self control may be consciousness on the Barratt's Impulsivity Scale. This type of surrogate measure of brain pathways is termed '*endophenotyping*,' as both of these measures although not measured in direct relation to foods have been linked to maladaptive eating behaviours (Bogg & Roberts, 2004, Nederkoorn et al.,2010) and related to the prefrontal cortex (Aron & Poldrack, 2006, De Young et al. 2010).

2.2.1 Suitability of neurocognitive tests to measure impulsivity

Many neurocognitive tools have been used to measure brain mechanisms related to obesity, particularly eating behaviours. These include functional neuroimaging (Batterink et al., 2010, Killgore and Yurgelum-Todd, 2005, Martin et al., 2010, Stice et al.,2008, Wang et al., 2010), electrophysiology (Nijs et al., 2010, Silval et al., 2002), non-invasive brain simulation (Camus et al., 2009, Fregni et al., 2008, Uher et al., 2005), hormonal manipulation (Batterham et al.,2007, Farooqi et al., 2007, Malik., 2008) and genetics (Stice et al., 2011). Such methods are useful for understanding the neural basis of food choice and obesity. Neurocognitive measures are too labour intensive to use as population studies which are increasingly necessary to understand the multivariate, multilevel determinants of obesity.

2.2.2 Trait impulsivity versus State impulsivity

According to trait theory, personality traits are stable over time, differ between individuals and influence behaviour (Boeree, 2006). The wide range of impulsive phenomena is reflected by the array of methods by which personality theories conceptualise impulsivity. It is further reflected by the various self-report measures used by trait theorists, which have focused on group statistics to siphon distinct aspects of impulsivity (Cattell, 1965). In contrast to personality measures, behavioural measures tend to capture more narrowly defined components of impulsivity (Eisenberg et al., 2007) and therefore has been used as measure of state-impulsivity (Christodoulou, Lewis, Ploubidis, & Frangou, 2006; Lai, Ip, & Lee, 2011; Swann, Lijffijt, Lane, Steinberg, & Moeller, 2009).

2.3 Models of behavioural impulsivity

The work of psychologists and neuroscientists studying impulsivity has always focused on self-control. Self-control is attributed to an executive system that regulates on going processes. To date, models of self-control and impulsivity have attributed self-control to an ill-defined set of 'homonculi' that are assumed to do jobs like 'response inhibition' or updating without really explaining how they do so (Logan, 2003). It is also important to understand that control takes place across different time scales. Personality theories and those related to behavioural economics describe impulsivity as being an automatic process. In the realms of behavioural theories, impulsivity is considered a function of executive control, meaning processes are considered to be slower, effortful, rational and goal directed. Executive control is used as an umbrella term for the functions of the cognitive system that allow people to regulate their behaviour towards higher order goals or plans. These involve organising, monitoring, and altering the settings of lower level cognitive processes such as stimulus detection and motor programming (Hazy, Frank, & O'Reilly, 2006; Logan & Gordon, 2001; E. K. Miller & Cohen, 2001). In clinical, social and cognitive psychology, individual or group differences in controlling actions are attributed to variation in the effectiveness of a single control function or mechanism. Two of the commonly used mechanisms include: response inhibition and temporal discounting.

2.3.1 Inhibitory control

Response inhibition is considered a key component of executive function (Andres, 2003; Aron, 2007; Stuphorn & Schall, 2006). Inhibitory control is the ability to stop or supress responses that are no longer required or deemed inappropriate. It is a dynamic concept and supports flexible and goal-directed behaviour in an ever changing environment. An everyday example of response inhibition may be an emergency stop whist driving when a cat runs across the road. The paradigm used most often for the measurement of response inhibition is the laboratory setting is the stop-signal paradigm (Logan & Cowan , 1984).

2.3.1.1 Stop- signal paradigm

In the stop signal paradigm participants perform a choice reaction time task. In the go task, also referred to as the primary task, subjects have to respond to the shape of a stimulus in a uniform fashion. For example, pressing the left key for a circle or the right key for a square. On given number of trials the go stimulus will be followed by an auditory signal (the stop signal), which instructs subjects to withhold their response. In young adults, eye movements, hand movements, key presses, squeezes and speech can all be stopped in about 200 msec (Logan and Cowan, 1984). The similar latencies across tasks and effector systems suggest that stopping relies on an age related modal process. Typically, subjects can inhibit their response when the stop signal is presented close to the go signal but becomes more difficult when the stop signal is presented close to the moment of response execution. In light of these findings Logan proposed the ‘race model’, whereby ones performance on this task can be explained by a race between a go process and a stop process.

2.3.1.2 The Race Model

The race model assumes a race between the stopping and the go process. In order to understand this model one must understand some basic definitions (Figure 2-2):

Go signal. This is primary stimulus to which the participant is asked to respond to.

Go process. The intended action by the participant to react to the go signal.

Stop signal. An auditory stimulus which signals participant to stop the go process.

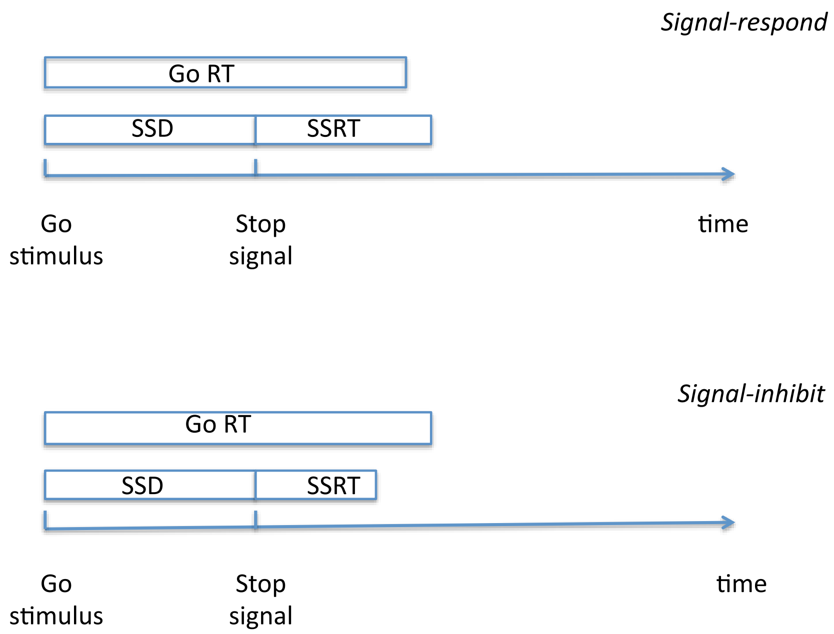
Stop process. The point in time at which the individual attempts to terminate the go process.

Stop signal delay (SSD). Delay between the stop signal and go signal. Subjects can stop their response only when the SSD is short (i.e 50ms).

Stop Signal Reaction Time (SSRT). This is the main variable of interest and describes the difficulty of the stop process and the latency of the stop process.

Logan (1981) modelled the performance on the stops signal task on a horse race. Between the go process and the stop process. When the stop process finished before the go process (RT> SSRT+ SSD), response inhibition is successful and no response in emitted (signal inhibit, Figure 2). However, when the go process finishes before the stop process (RT< SSRT +SSD), response inhibition is unsuccessful and the response in incorrectly inhibited (signal respond). Logan (1981) used the horse race model to estimate the otherwise unobservable latency of the stop process.

Figure 2-2 A diagram illustrating the the Race Model for inhibitory control



2.3.2 Intertemporal choice

2.3.2.1 Lowenstein and Temporal Discounting

Intertemporal choice has been mentioned under Lowenstein's model of impulsivity and can be defined as deciding between actions whose consequences are experienced at different time-points. Individuals who are impulsive will often choose a small immediate reward over a larger distant one, implying a decrease in reward value with increasing delay into the future. This effect, which is often described in behavioural economic theory, is known as temporal discounting and can be modelled using continuous decreasing function (Laibson,1997), known as a discounting or hyperbolic function, the rate parameter of which is known as the discount rate (Samuelson, 1937). Impulsivity is hallmarked by a high discount rate.

Loewenstein and colleagues (2001) propose three constituents: impulsivity, defined as the degree to which an individual acts in a spontaneous, unplanned fashion; compulsivity, defined as the tendency to make plans and stick with them, and inhibition, defined as the ability to inhibit automatic response to the appetites and emotions that trigger impulsive behaviour. All of these concepts could be considered as individuals exerting an inner force (power of will*)* to override some type of underlying motivation. As suggested by Loewenstein (2000), exertions of willpower always involve sacrifices of immediate utility for the sake of future benefits, also known as 'temporal discounting'. For example, willpower is used to suppress a desire for high-calorie food when it is easily accessible, and to avoid indulgence in the instant satisfaction of doing something else other than exercise. Hence, individuals who want to lose weight but lack the willpower and cognitive resources will find it more difficult to stick to their diet and exercise plans, leaving them at a higher risk for obesity. Lowenstein's model of impulsivity has formed the foundation for experiments in behavioural economics. Temporal discounting in the literature has assessed both monetary and food rewards. There is greater evidence to support the use of monetary rewards over food or hypothetical questions. Several studies have demonstrated that many established properties of financial discounting also apply in the health domain.

2.3.2.2 Temporal Discounting and obesity

There are in particular a number of studies that have looked at the relationship between intertemporal discounting and body weight outcomes. Many are still preliminary and exploratory in nature, but provide interesting evidence on the topic. Empirical studies looking at discounting and health usually search for an association between the health outcome of interest, and either a monetary discount rate, or a health-domain discount rate (and sometimes both). It is difficult to ignore that the current fiscal situation has resulted from increased borrowing has paralleled the rise in obesity globally. Lomlos, Smith and Bogin (2004) test the relationship between intertemporal discounting and obesity using savings and debt as an indicator for intertemporal preferences. Using time-series ratios they discuss how obesity rates have followed similar trajectories to savings and debt ratios over recent years as evidence of increased discount rates leading to obesity. The study also examined the correlation between cross-sectional data on countries net domestic saving rates and obesity rate. These associations are interpreted with caution by the authors, as there are many confounding social and economical variables in play for both variables. A second study, which regressed BMI, based on savings that were a proxy of intertemporal discounting and a set of control variables found a positive relationship with stronger evidence for males than females (Smith, Bogin & Bishai, 2005). Similarly Borghans and Glosteyn (2006) investigated the relationship between BMI and a variety of indicators of intertemporal preferences including a battery of six choice based questions in the monetary domain, a matching question with regard to the number of days in a vacation and 25 questions related to intertemporal preferences, including statements of saving behaviour, riskness of investments, planning and attitude to the future. This study also noted a greater increase in BMI amongst those with higher discount rates.

In addition, weight studies have also investigated the relationship between intertemporal preferences in diet choice as a proximate cause of weight determination. Based on Grossman's (1972) model of health capital diet is assumed to be determined by market factors, sociocultural factors and future discount rate. The empirical results show that the variables chosen to proxy for intertemporal discount rate were all individually important for diet choice. Therefore, a theoretical basis exists for the effect of monetary intertemporal discount rates on body weight outcomes although there is no existing work that focuses on its role in weight loss.

Actual food rewards is an alternative to using monetary discounting or hypothetical health/disease choices. Examples include asking participants how much they plan to eat/avoid certain food products over a given time period and then measuring any discrepancy with actual recorded behaviour (Hall et al., 2008) or measuring how much participants eat in a particular context, such as in a bogus food tasting test (Herman & Mack, 1975). Food rewards have only been shown to distinguish between obese and non-obese children and the effect size was small (Johnson, Parry & Drabman, 1978; Bonato & Boland, 1983). Such tasks have not shown any consistent findings in adults to support their use to predict weight loss. Similarly, a set of hypothetical health scenarios may be used to operationalise temporal discounting but it is difficult to transfer these options into the adolescent and child subgroups, as there is no currently validated tool. Whilst health and food related options might be more specific than neurocognitive tasks, these measures have not been positioned within a brain-based conceptual framework. In addition, studies using these approaches tend to use idiosyncratic tasks, making cross-study comparison more difficult. For further support of the early development for the concept of money see the conclusion of chapter 7.

The concept of temporal discounting is highly relevant to health and lifestyle choices, especially obesity. Many health-relevant choices involve a trade-off between their short-term and long-term consequences. For example, fast-food might be immediately convenient and tasty, but if consumed regularly is likely to lead to weight gain. Grossman (1972) suggested that if engaging in healthy behaviours is considered equivalent in economic terms to making a long-term investment, then discount rates ought to be able to explain whether people "invest" in such behaviours. It is relevant to ask whether, in attempting to test Grossman's theory, we should measure discount rates for relevant health outcomes or for more conventional monetary outcomes.

Chapman and Elstein (1995) suggested that the difference in discount rates between health and money domains might be accounted for by a phenomenon know as magnitude effect, leading to higher discount rates for health if the health outcomes were deemed less valuable by the subjects relative to the monetary outcome. This lack of correlation might simply reflect the fact that hypothetical health outcomes do not motivate temporal discounting in the same way as money which is supported by the high prevalence of zero discounting for health or a lack of discounting. A possible hypothesis to explain the high proportion of zero health discounting observed, would be that people have difficulty in imagining or evaluating hypothetical health states (Patrick, Starks, Cain, Uhlmann & Pearlman, 1994). Similarly, discount rates may be lower when health outcomes are described in purely experimental terms rather than as a receipt of a primary or secondary reinforce. Both theories would allow for the possibility that real-world health choices involve temporal discounting to a greater degree (i.e discount future outcomes more) than hypothetical health discounting paradigms. Therefore, one would expect in vivo health choice to correlate more strongly with monetary discount rates than with hypothetical health discount rates, a prediction which is generally supported by the handful of studies that have made this comparison (Baker, Johnson & Bickel, 2003; Chapman & Coups, 1999; Chapman et al., 2001; Khwaja, Silverman & Sloan, 2007).

2.4 Why study Impulsivity

Impulsivity is part of the human condition. At some point, in all of us, our disciplined sense of control is likely to collapse. Impulsivity is an important construct contributing to many public health concerns (Black & Moyer, 1998; Donohew et al., 2000; Hamburg, 1998; Shaffer & Korn, 2002). The consequences of these impulsive behaviours are wide arching and understanding the mechanism behind impulsivity and how these mechanisms function or malfunction at different times in different people can lead to novel treatment and prevention options.

2.4.1 Impulsivity in psychiatry

Impulsivity is directly mentioned in the DSM-IV diagnostic criteria for several disorders and is implied in the criteria for others (DSM-IV, 1994). Psychiatric conditions in which impulsivity contributes to the diagnosis include: ADHD, Antisocial Personality Disorders, substance misuse, mania and conduct disorders. In the fifth edition of the DSM, a new chapter has been added to include a subset of psychiatric disorders termed 'impulse disorders not elsewhere classified', which consist of kleptomania, pathological gambling, pyromania (fire starting) and trichotillomania (a compulsion to pull one's hair out). These are disorders characterised by problems in emotional and behavioural self-control (DSM5.org, 2013). The psychiatric model of impulsivity is well characterised into five behavioural stages: an impulse, growing tension, pleasure of acting, relief from an urge and finally guilt (Wright, Rickards, & Cavanna, 2012).

2.4.1.1 Antisocial Personality Disorder

The DSM-IV defines antisocial personality disorder as a consistent pattern of disregard for and violation of the rights of others occurring since the age of 15. Impulsivity or a failure to plan ahead is listed as a core criteria for this disorder. Those who have this personality disorder have a disregard or violation for the rights of others and are often involved in a history of criminality. Barratt and colleagues have based subtypes of antisocial personality disorder on the measurement of impulsivity via a structured interview. The gradation of impulsive acts in prison inmates supports a basic biological or behavioural distinction (Barratt et al., 1997).

Serotonin-based metabolites have been implicated in subjects who exhibit impulsive violence (Linnola et al, 1983). Another possible explanation for the aetiology of impulsivity in individuals with antisocial personality disorder is traumatic brain injury. Damage to the frontal cortex is thought to be the source of impulsivity (Jentsch & Taylor, 1999). Bechara and colleagues (1994) have shown that individuals with prefrontal cortical injuries have deficits in distinguishing between choices that lead to either good or bad outcomes.

2.4.1.2 Borderline Personality Disorder

Impulsivity is one of the DSM-IV diagnostic criteria for borderline personality disorder, as are affective instability and identity disturbance. In boderline personality disorder, patients often have two types of impulses that they find difficult to control: firstly, an impulse to self-harm and secondly, an impulse to engage in reckless and irresponsible activities, such as binge drinking, drug abuse, going on spending or gambling spree or having unprotected sex with strangers. Links and colleagues (1999) showed by a stepwise multiple regression that the ‘impulse action’ subscale score from the Diagnostic Interview for Borderline Patients best predicted borderline psychopathology at seven years follow-up. In addition, impulsivity is an important factor in suicide attempts in patients with borderline personality disorder (Mann, Waternaux, Haas, & Malone, 1999).

2.4.1.3 Bipolar Disorder

The diagnosis of bipolar disorder is almost impossible without encompassing impulsive behaviours. People with bipolar disorder oscillate between periods of depression, where they feel low and lethargic, and mania, where they feel high and overactive. Episodes of mania are ubiquitous with impulsive actions and correlated with the severity of manic symptoms in mildly ill patients (Swann et al., 2001). Data in bipolar disease suggests that impulsivity has both state- and trait- dependent components. The depressive symptoms may also be associated with impulsivity when suicide ideation is present (Corruble, 1989). Impulsivity is a measure of susceptibility to mania in adolescents (Sunohara et al., 1999), related to risks of complications like suicide (Corruble et al., 1999) and substance abuse (Patton et al., 1995).

2.4.1.4 ADHD and Conduct Disorder

Impulsivity along side inattention and hyperactivity are symptoms used to subcategorise children with ADHD symptoms (Sykes et al., 1973, O'Toole et al., 1997, Halperin et al., 1988 & Dykman et al., 1979). Behavioural laboratory measures of impulsivity have shown children with ADHD to be more impulsive than a normal comparison group. Individuals of the impulsive/hyperactivity subtype are more likely to have oppositional defiant disorder, conduct disorder (Willcut et al., 1999) and an increased risk of criminality (Babinski et al., 1999). The use of psychostimulants to treat ADHD and conduct disorder supports the role of neuronal dopamine pathways in their aetiology. Other supporting evidences for the role of the neurotransmitter dopamine in impulsivity include: genetic studies which have found a relationship between dopamine transporter and D4 receptor alleles and ADHD (Daly et al., 1999, Smalley et al., 1998) and finding increased activity of dopamine-synthesising enzymes in brains of children with ADHD (Ernst et al., 1999).

2.4.2 Impulsivity in Addictive Behaviours

Impulsivity has been shown to be high is sub-populations with addictive behaviours. Self-report personality questionnaires have shown that, in the prisoner population with a history of substance misuse (cannabis, stimulants and alcohol; Brunelle et al., 2009) and individuals with alcohol dependence (Ibanez et al., 2010), they were more likely to be impulsive than the normal population. Behavioural tasks of impulsivity have shown that sufferers of drug addiction (Moeller et al, 2002) are more impulsive using a stop signal task (Fillmore & Rush, 2002) and the delayed discounting paradigm (Coffey et al., 2003), whereas individuals abstinent from alcohol (Mitchell, Fields, D'Espositos & Boettiger, 2005) were found to be more impulsive than a control group using the temporal discounting task only.

In addition to addictive behaviours, impulsivity has been associated with poor health related behaviours. Self reported measures of impulsivity are a predictor of initiating smoking (Grano, Virtanen, Vahtera, Elvainio & Kivimaki, 2004), smoking status and dependence (Flory &Manuck, 2009). Those found to be impulsive were more likely to partake in risky sexual practices (Khurana et al., 2012), aggressive tendencies (Barratt & Slaught, 1998; New et al., 2002) and suicidal ideation and behaviour

(Conner, Meldrum, Wieczorek, Duberstein & Welte, 2004; Hull-Blanks, Kerr, Kurpius, 2004).

2.4.3 Associations between self-report measures and experimental measures

Results traditionally suggest that personality measures of impulsivity intercorrelate well with each other but poorly with measures of inhibitory control (Milich & Kramer, 1984; White et al., 1994). It is unclear whether the apparent lack of relationship represents the measurement of distinct and unrelated concepts, measurement error, or variability in the measures used.

The most commonly used personality questionnaires to assess the spectrum of impulsive behaviours are the Barratt Impulsivity Scale (BIS-11), Eysenck's questionnaire (I7) and Dickman Impulsivity Inventory. All three questionnaires are based on different concepts of impulsivity as described above.

Reynolds and colleagues (2006) compared questionnaire based measures of impulsivity against SSRT, TDT, go/no-go and risk taking. There was only one statistically significant correlation below r=0.3. There was a positive correlation between Cognitive Complexity of the BIS-11 and errors of commission on the Go/No-Go task. Factor analysis of behavioural measures found two independent latent variables: one corresponding to impulsive response (SSRT, go/no-go task) and the other corresponded to impulsive choice (TDT, risk taking). Correlations were sufficiently low and the study concluded that 'impulsive choice' and 'impulsive response' tap into different cognitive responses.

Other studies which have failed to show any correlations between personality and behavioural measures of impulsivity (Swann et al, 2002; Lane et al, 2003, Zermatten et al, 2005, Dom et al 2007). As a rule, the correlation coefficient linking behavioural and questionnaire measures of impulsivity rarely exceed r=0.4 (Moeller et al., 2002). Enticott and colleagues (2006) compared the association between the BIS and four behavioural paradigms of inhibitory control including motor inhibition, the SST, the Stroop and negative priming. Stroop conflict correlated significantly with non-planning, attentional motor and overall self-reported impulsiveness; motor disinhibition correlated significantly with non-planning impulsiveness and response variability was associated with motor impulsiveness.

2.5 Neuronal Circuitory

The two behavioural facets of impulsivity, inhibitory control and temporal discounting, were studied in this study using computerised cognitive tasks as an intermediate marker of brain dysfunction (endophenotyping). Neuroscience research has found three interacting brain networks that mediate reactive (or reflexive) and proactive (reflective) behavioural control (Fox, Corbetta, Snyder, Vincent, & Raichle, 2006; Corbetta & Shulman, 2002; Seeley et al., 2007; Sridharan, Levitin, & Menon, 2008). The 'salience network' (which includes the inferior frontal gyrus and anterior cingulate cortex) shows increased activity upon detection of a salient event or stimuli in the environment. Functional imaging has shown the salience network to be a mediator of top-down regulation. The visual system is known to be selectively activated in response to food (Simmons, Martin, & Barsalou, 2005). Obese individuals exhibit excessive visual processing of high caloric foods, especially in the fasting state (Kullmann et al., 2013). In order to overcome this, they may use cognitive strategies such as restraint or disinhibition. Therefore, inhibitory control was used as a surrogate marker of activity in the salience network.

The default mode network (DMN) is the second brain network which shows activity in the ventromedial prefrontal cortex, posterior cingulate cortex and the hippocampus (Buckner, Andrews-Hanna, & Schacter, 2008). It is related to top-down control and hence involved with mentalising decisions before action, providing a sense of self and future planning. The DMN is responsible for controlling our behaviours leading to the attainment of long-term goals. It is thought that activity in the default mode network represents the neural mechanism by which impulsive individuals give greater weight to immediate gratification than to long-term consequences of their action, this was tested using the temporal discounting paradigm using monetary rewards (Shannon et al., 2011). In summary, normal weight, less impulsive individuals, rely more on proactive control (subserved by the default mode network), while more impulsive, obese individuals rely more on the reactive behavioural control (subserved by the salience network).

The final network is executive control, which is involved in voluntary top-down control and includes the prefrontal cortex, posterior parietal cortex, and the frontal eye-fields (Astafiev et al., 2003; Buckner & Carroll, 2007; E. K. Miller, 2000; Sakagami, Pan, & Uttl, 2006). The executive control network is operant when extra cognitive control is required to process sensory information for immediate actions. If the salience network were to represent the go-trials of the stop signal task, the executive network would be represented by the no-go trials as it works in antagonism with the salience pathway. All three networks are interconnected neuronal networks. Therfore improvement in for example the stop signal task can mean a reduction in the salience of the stimulus, reduction in activity of the network or an increase in executive control.

SUMMARY

- Impulsivity is defined as 'behaviour without adequate thought, the tendency to act with less forethought than do most individuals of equal ability and knowledge or a predisposition towards rapid, unplanned reactions to internal or external stimulus without regard to the negative consequences of these reactions'.
- Impulsivitiy as part of both an automatic behavioural pathway and executive control.
- Personality models of impulsivity are described: Eysenck and Eysenck, Dickman's, Barratt's, Cloninger's, Gray's, BIS/BAS, Five Factor Model.
- Behavioural models of impulsivity including inter temporal choice and inhibitory control correlate poorly with personality models.
- Impulsivity contributes to the diagnosis of common psychiatric disorders including: borderline personality disorders, bipolar disorder and substance misuse.
- Endophenotyping involves the use of behavioural measures to indirectly study brain pathways.
- The salience network will be studied by performance on the inhibitory control task and the default mode network will be studied by performance on the intertemporal choice task.

Chapter 3 Systematic Review: The role of impulsivity in obesity as measured by inhibitory control

3.1 Introduction

Executive function is a broad term to describe actions and brain functions that underly flexible goal directed behaviour. The importance of executive function in eating behaviour has been studied in obesity and with relation to BMI. Miyake and colleaguues (2000) describes executive function as a combination of response inhibition, attention shifting and working memory. The current review shall focus on behavioural measure of inhibitory control and their role in obesity and eating behaviours. The advantage of behavioural measures have been described fully in Chapter 1 (see Advantages of neurobehavioural measures) and a summary can be found in Table 3-1.

Table 3-1 Advantages of neurobehavioural measures

Performance can be linked to neuronal pathways in the brain
Feasible for large scale studies
Quantify a particular behaviour
Provide objective measurements
Less prone to observer bias

Response inhibition will be described as inhibitory control for the remainder of the review. This process of inhibitory control has been described by the 'executive control model' (Logan, 1985). According to this model, inhibition is a top down process in which a high order system interacts and controls a lower order system. The lower order or subordinate system is depended on the higher order executive system for its instructions and resources. Therefore, subordinate choice to act out one intention can be stopped in some cases and replaced by a new intention (Band & van Boxtel, 1999). Logan (1989) describes how the executive system can inhibit the subordinate system and proposed the stop signal paradigm to study this inhibitory paradigm. Barkley (1999) from studying ADHD described three interrelated processes of behavioural inhibition: the ability to withhold a prepotent response, the ability to stop an ongoing response and interference control. Interference control, on the other hand, is the ability to protect a delay in the decision to respond an ongoing activity (resulting in a withheld response) from interfering events and responses (Grodzinsky & Barkley, 1999). These categories also describe the taxonomy of the inhibitory construct described by Nigg (2000). Behavioural tasks have been described for each of these categories of inhibitory control. The go no-go task, continuous performance tests, stop signal paradigm and the stroop task are examples of such computerised tasks. Deficits in inhibitory control have been classically studied in drug addiction (Moeller et al., 2002). The abnormal neural pathways specifically dysfunction of the prefrontal cortex have also been found in obesity (Goldstein & Volkow, 2011). The use of neurocognitive tasks in the support the theory that the obese have impulsive tendencies:

- Obese people entering weight reduction programmes have greater deficits in impulse control than lean people using self-report questionnaires (Guerrieri et al., 2009)

- There have been found to be a link between obesity and impulsivity in the comorbidity between obesity and ADHD in children (Winstanley, Eagle, & Robbins, 2006).
- The use of alcohol, which causes a decreased capability to inhibit responses, increases food intake (Caton, Ball, Ahern, & Hetherington, 2004).

Reviews to date have focused on temporal discounting on the sensitivity to reward and health behaviours and neurobehavioural measures and obesity (Story, Valev, Seymour, Darzi & Dolan, 2014; Vainik, Dagher, Dube & Fellows, 2013). However, the literature based on inhibitory control and obesity is yet to be reviewed, which is the focus of the present review.

3.2 Search strategy

On 26.12.2013 a topic search of the medline database was conducted. The search terms included impulsivity OR inhibitory control OR stop signal task OR go no-go task OR stroop task AND obesity OR weight OR BMI. The search included articles from 1985 to the present day. The search was designed to exclude studies involving animals and work not related to obesity and psychology, resulting in a total of 397 papers. Based on the title and abstract we included papers that examined the relationship between the neurocognitive measures of interest (inhibitory control) and one or more eating-related measurements: BMI, BMI change or laboratory food intake measures. We excluded results from a particular clinical population such as smokers, addiction, those with a psychiatric disorder and ADHD as these are populations known to have abnormal inhibitory control and would bias the findings. Studies with eating disorders were also excluded as these individuals are variably impulsvie as described in the introduction and obesity is not classifed as an eating disorder according to the ICD-11 criteria. Only papers in English providing statistical data confirming the presence or absence of an effect were included.

3.3 Search Results

Our search identified 21 studies, which used three computerised measures of inhibitory control. Seven of the studies used the Go no-go task, nine studies used the SST and four studies used the Stroop task. The test-retest reliability and internal consistency of these measures related to obesity and eating behaviour can be found in Table 3-2. Seventeen studies measured inhibitory control on an adult female population. The three remaining studies were on groups of mixed sex adolescents aged 11 to 15 years old. Seven of the studies were on obese participants and studied the relationship between BMI and inhibitory control. The remainder of the studies looked at the role of impulsivity in food intake (Guerrieri, Nederkoorn, & Jansen, 2007; Hall, 2012), dietary restraint, (Jansen et al., 2009) weight gain (Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010) and its potential role in the intention-behaviour gap with regard to individual food consumption (Allan, Johnston, & Campbell, 2010; Allan, Johnston, & Campbell, 2011).

Table 3-2A list of studies using behavioural measures to investigate obesity and eating behaviours

Authors	Sample	Group/ Obese population	Task/ Measure	Visual/ Auditory	Food related task stimulus	Experimental/ Observatory	Food Eating ED	Relation impulsivity-BMI	Mean Age	Mean BMI	BMI	Comments
Pauli-Pott et al. (2010)	177	Obese children	Go no-go/Stop Signal (Reaction times, invalid reactions)	Visual	No	Observational	No		11.3	29.3 (SD 4.3)	X	1. Error rates to predict obese vs. non-obese in younger age group(<11 years old). 2. In younger children age moderated BMI (using go no-go task). However not found in adolescents. Inattention cores differentiated between age groups-children being more attentive than adolescents as measured by reaction times.
Jansen et al. (2009)	64	Adults-female	Stop Signal Task/dietary restrint	Auditory	No	Experimental	Yes		22.4 (SD 2.6)	19.1 (SD 1.3)		High restrint eaters only over eat when highly impuslive too. Seen under all experimental conditons: control, preload sight of food).
Loeber et al (2012)	20	Adults - mixed	Go no-go Task 1.Reaction times in go trials	Visual	No	Observational	No	No	47.9 (SD 12.5)	38.8 (SD 6.3)	X	Both obese and normal were faster at responding to go-trials.

			2. responses to distractors (commission errors) 3.comission errors (failing to respond to target words)									
Guerrierie et al. (2007)	68	Adults-female	Stop Signal Task (SSRT)	Auditory	No	Experimental	Yes (Bogus)		20.3 (SD 3.4)	21.8 (SD 3.0)		Median-split using SSRT was unable to find influence of impulsivity on flood intake (SSRT 159.44 ms).
Nerderkoorn et al. (2010)	74	Adults-female Obese	Stop Signal Task (SSRT) IAT	Auditory	Yes. IAT	No	No	No	19.7 (SD 1.9)	21.5 (SD 2.3)		1. For participants with a high Implicit Preference for snack food, poor inhibitory control significantly influenced weight change. 2. Less effective response inhibition gained more weight than participants with more effective response inhibition.
Nederkoorn et al (2006)	32	Adolescents Obese	Stop Signal Task (SSRT)	Auditory	No	No	No	Yes (Corr.)	13.7	26.6 (SD 4.2)	X	Obese found to be more impulsive on SSRT (186.9 (SD43.5) vs. 166.4 (SD 35.7). 2. SSRT correlated with those who lost most weight during intervention.3 SSRT did not

												differentiate between binge eaters and non-binge eaters.
Jasinska et al. (2012)	204	Adults-Mixed	Go no-go (Error Rates)	Visual	Food images	Observational	No	No	19.0 (SD 0.9)	23.5 (SD 4.0)	X	1. Inhibitory control (rate of false alarms) significantly associated with emotional eating scores (DEBQ score). 2. Rate of false alarms had a negative association with tasty healthy choices of the food choice task.
Nederkoorn et al. (2006)	31	Adults-Women Obese	Stop Signal Task (SSRT)	Auditory	No	Observatory	No	Yes	39 (SD 5.3)	40.9 (SD 6.6.)	X	Obese showed prolonged SSRT (in last of 4 blocks)-overall no significance.
Nederkoorn et al, (2009)	57	Adults-female	Stop Signal Task (SSRT)	Auditory	No	Experimental	Yes (Bogus)	No	20.0 (SD 1.4)	22.0 (SD 1.6)		1. Caloric intake correlate significantly with inhibitory control.2. Hierarchal linear regression showed those who were hungry and impulsive ate the most.
Verbeken et al. (2009)	41	Children Obese	Stop Signal Task (SSRT)	Visual	No	Observatory	No	Yes	12.0 (SD 1.5)	32.3	X	Obese group had less efficient inhibitory control (227 (SD 47.7) vs. 261.9 (SD 63.0)
Guerrieri et	66	Adults-Female	Stop Signal Task	Auditory	No	Experimental	Yes	No	20.8 (SD	22.3 (2.6)		1. Caloric intake was greatest for

al. (2009)			(SSRT)				(Bogus)		2.6)			non-dieters with induction of impulsivity. 2. Current dieters increased caloric diet in response to inhibition.
Hall et al. (2008)	64	Adults	Go no-go task	Visual	No	Prospective, non-experimental	No	Yes	19	22.1	X	Behaviour intention for physical activity and consumption for fruit and vegetable was significant for those with strong executive function.
Allan et al. 2010	114	Adults	Go no-go Task (Error Rates)/ Stroop (Average median reaction times)	Visual	No	Experimental	2 studies looking at dietary monitoring tasks.	No	Study 1 (22) Study 2 (22)			Performance on Stroop Task only was a predictor of number of snacks consumed and hence the intention-behaviour gap.
Ratcliff et al. (2010)	264	Adults	Go no-go Task (Error Rates)	Visual	No	Observatory	No	No	18.3 (SD 0.6)	43/264 obese	X	Go No-go task did not predict % Body Fat.
Wong et al. (2009)	96	Adults	Go no-go task (Performance Index [(No Go Accuracy/RT)x	Visual	No	Observatory	NO	No	19.5 (SD 2.2)	Not recorded		Go No-go task did not predict intention and prospective behaviour of breakfast consumption.

			100])								
Hoffmann et al. (2009)	118	Adults-Female	Go no-go task (SSRT)	Auditory	Yes (Images)	Experimental	Yes (Bogus)	No	23	22.2	Automatic affective reactions have a stronger impact on eating behaviour for individuals lower inhibitory control.
Houben et al. (2011)	29	Adults-Mixed	Stop Signal Task (SSRT)	Visual	No	Experimental	Yes (Bogus)	NO	21.2 (SD 1.8)	23.1 (SD 4.3)	1. Food intake higher in those with low inhibitory control. 2. Inhibition manipulation decreased consumption of food paired with stop signal (stop food. In participants with high inhibitory control, impulsivity manipulation increased consumption of go food relative to control food.
Allan et al. (2010)	62	Adults	Stroop Test (Incongruent-Neutral RT)	Visual	No	Experiment	Yes (Bogus)	Yes	20.4 (SD 7.1)	22.6	1. Poor Stroop performance associated with greater chocolate consumption. 2. Stroop associated with higher BMI in normal weight participants.
Gunstad et al. (2007)	408	Adults	Stroop Test (Verbal Interference)	Visual	No	Observatory	No	Yes (Verbal interference	Younger: 32.4 (SD	Younger: 28.4 (SD	Normal weight individuals outperformed overweight/obese

								negatively correlated with BMI)	9.1) Older: (60.4 (SD 7.6)	4.4) Older: 29.2 (SD 3.5)		participants on Stroop Task (verbal interference)
Phelan et al. (2011)	29	Adults(Obese and Weight loss maintainers)	Stroop Test (Average median reaction time- Correct trials)	Visual	Yes (words)	Observatory	No	No	WLM: 48.5 (SD 11.4) Obese: 48.3 (SD 7.6)	WLM: 23.7 (SD 1.6) Obese: 34.3 (SD6.7)	X	1. Weight loss maintainers showed slower reaction times for high calorie food than obese and normal weight persons. 2. Obese were fastest to react to high calories food.

3.3.1 Reliability

Unlike self-report questionnaires of impulsivity, the validity and reliability for behavioural tasks were difficult to determine from the studies identified. Most of the tests used report the construct and predictive validity of a given measurement (Table 2-3). A test is said to have construct validity if it demonstrates an association between inhibitory control scores and the impulsivity theoretical trait. Whilst predictive validity occurs when the criterion measures are obtained at a time after the test, for example, impulsivity measure and how likely someone is to lose weight. However, validity of a test is redundant without high reliability. The reliability of a measure determines the maximum possible correlation between the measure and a given outcome. Table two summarises the reliability scores of the three commonly used measure of inhibitory control. The test-retest reliability measures the stability of a measurement from one occasion to another. A good test-retest reliability was taken to be >0.70 making it more likely that the same concept is measured on both occasions and less likely to be prone to errors. Other reasons for poor test-retest reliability include a learning effect on the task with repetitions or a change in the individual's motivational state. Internal consistency determines how well different components of a test measure the same construct. Therefore, a poor internal consistency taken to be a value <0.70 means that some components of the measurements do not contribute to the outcome of interest and may be measuring an unrelated concept. The presence of a very high internal consistence taken to be a value of >0.90 could also be detrimental as a measurement may only be recording a narrow component of the interested item (Streiner, 2003). All of the tests had a test re-test reliability available. For the Go no-go task, the omission and commission errors were the more reliable (>0.70) and the reaction time was the least reliable measure of impulsivity (0.63). The Stop signal reaction time also had a good test re-test reliability (0.72). For the Stroop task, the additional time taken to name the ink colour in the incongruent relative to the congruent condition was shown to have a low test re-test reliability (0.46). However the test re-test reliability was much improved for times presenting incongruent-neutral conditions (0.73) and for tests measuring the reaction time to incongruent stimulus (0.79-0.87). The internal consistency was not available for all the various components of the inhibitory task test and for the stop signal task the reliability scores have been obtained in studies in children and may be different in the adult population.

Table 3-3 Reliability and internal consistency of commonly used behavioural measures

a Cronbach alpha; ***b*** split half reliability; ***c*** correlation; ***d*** Interclass Correlation Coefficient

Measure	**Test re-test reliability**	**Internal consistency**	**Studies**
Go No-go Task	0.09[d]	0.73-0.95[a]	Schweiger et al. (2007)
Omission errors	0.72[d]		
Comission errors	0.76[d]		
Reaction time	0.63[d]		
Stop Signal Task			Friedman et al. (2009)
SSRT	0.72[d]	0.75[b]	
Stroop (single stimulus)			Friedman et al. (2009)
Incongruent-congruent	0.46[c]	0.87-0.88; 0.91	
Incongruent-XXXX	0.73[c]		
RT to incongruent	0.79-0.87[c]		

Table 3-4 A table illustrating how to perform behavioural tasks and their measurable outcomes

Task Name	Manipulations	Main dependent variable(s)
Stop Signal Task	The SST consists of GO and STOP trials. During the go-trials, the letter O or the letter X is presented for 1000 ms on the centre of a computer screen, preceded by a 500 ms fixation point, also in the centre of the screen. The participant learns to press the button on the right side with the right hand when the X is presented and the button on the left side and with the left hand when the O is presented. The instruction during this choice reaction time task is to press the button as fast as possible. A crucial element of the task is that this learned response has to be inhibited during stop trials. During stop trials a stop signal, a computer-produced 100 ms 1000 Hz tone, is presented. The participant is instructed not to respond when she hears the tone. Between trials, the screen is blank for 1000 ms. Initially, the delay between the go signal (X or O) and the stop signal is 250 ms. Depending on the responding of the participant, a tracking procedure adapts the go–stop delay dynamically; if the participant succeeds in inhibiting the response, the go–stop delay is increased by 50 ms, thereby making it more difficult to inhibit the next trial. If the participant fails to inhibit the response, the go–stop delay is decreased by 50 ms, thereby making it easier to inhibit the next trial. The SST is designed to enable participants to inhibit 50% of the stop trials.	The stop-signal reaction time (SSRT), which is the estimated latency of stopping (Logan & Cowan, 1984). Longer SSRTs usually mean poorer inhibitory control. Invalid reactions can also be assessed.
Go-No go task	Participants are instructed to respond as quickly as possible to go stimuli (e.g. digit) but then to refrain from responding when a no-go stimulus is presented (e.g. letters). Go events usually occur with higher frequency than no-go events.	Responses to distractors (commission errors, i.e., failing to respond to target words).

Implicit Association Test (Greenwald, McGhee & Schwartz, 1998)	The IAT measures the strength of evaluative associations towards different concepts. In the study of Nederkoorn and colleagues (2010), the target category was food, and the attribute/ evaluative categories were "I like" and "I don't like." Evaluative stimuli were six positive and six negative pictures from the IAPS. The target stimuli were six food pictures, depicting a bag of crisps, chocolate, chocolate chip cookie, French fries, a hamburger and a pizza. The participant first completed a practice block in which only negative and positive pictures had to be categorized. In the next block, the first combined block (72 trials in a fixed random order) the participant had to respond to the positive category and food with one response key and to the negative category with the other response key. This assignment was changed in the second combined block such that the negative category and food shared a response key.	Response-latency measures, which involve the measurement of the time delay that occurs before a response (Average median reaction time).
Stroop Test (Golden, 1994)	This test consists of three forms, each containing 100 elements. The first form is made up of the words "RED", "GREEN," and "BLUE" ordered randomly and printed in black ink. In this condition, participants are asked to read aloud the words written. The second form consists of strings of "XXXX" printed in red, blue, or green ink. In this condition, participants are asked to name the color. The third form introduces the condition of interference, and it consists of the words from the first sheet printed in the colors of the second. In this condition, participants have to name the color of the ink and ignore the word.	Verbal interference Incongruent-Neutral RT

3.3.2 Distinguishing obese from non-obese subjects

Ten studies looked at the relationship between BMI and inhibitory control. Most studies did this by means of a direct cross-sectional comparison between obese and normal weight individuals. The first study found that impulsivity as measured by the error rates on the go no-go task did not significantly differ between the age groups, when they were divided into seven categorical factors between 8 to 15 years-old (Pauli-Pott et al., 2010). However, the difference in error rates reached statistical significance when using a stepwise regression. Here the body weight was the independent variable against which impulsivity and age were added to the regression. Therefore, age moderated the relationship between impulsivity and body weight. The higher the age related BMI, the greater the impulsivity scores. This relationship was found particularly in those 11 years-old or younger and not in adolescents. Two further studies using the go no-go task in adults have found no association between measures of impulsivity and weight. The first study tested food related words versus object words and found that both obese and normal weight groups were faster at responding to go-trials with food compared to go-trials with objects as the target category. There were also no differences between both groups in omission or commission errors (Loeber et al, 2011). Ratcliff (2010) correlated the error rates from the go no-go task against the percentage of body fat in 264 college freshman of whom 63 were clinically obese and found no relationship.

Three of four studies using the Stroop task found a difference in performance between obese and normal weight adults. Both studies that showed a difference between obese and normal weight participants used non-food related stimulus. Allan and colleagues (2010) used the difference in response time to an incongruent colour-

coloured word (e.g the word blue printed in red ink) and a coloured patch and found that poorer performance on the stroop test was associated with greater chocolate consumption and higher stroop scores were significantly associated with higher BMI. Gunstad (2007) used a Verbal Interference test in which the total number of correct responses on a colour-word condition was the measure of inhibitory control. Using a MANCOVA, BMI effects were shown on verbal interference; those who were obese or overweight under performed in comparison to normal weight individuals. Phelan and colleagues (2011) found that the use of food related words were able to differentiate obese individuals from normal weight participants by their significantly faster reaction times to high-caloric foods. This particular study also tested participants who had managed to maintain their weight loss for greater than three years. Such weight loss maintainers were found to have the slowest reaction time to high caloric foods of all three groups.

The final study to show a difference in impulsivity between obese and normal weight individuals used the Stop Signal Task. Nederkoorn (2006) used the stop signal paradigm with both an auditory and non-food related visual stop cues to differentiate between obese and normal weight adolescents (Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006). The same also differentiated between obese and normal weight women again using the SST. However, the difference in task performance was only evident on the fourth and final block of tests. This supports the notion of greater mental fatigue in this group and may be in line with the theory of ‘ego depletion’. In this theory self-control is viewed as analogous to a muscle. With greater use, ones cognitive become fatigued resulting in impulsive acts.

3.3.3 Inhibitory control as a predictor of increased food intake

Food intake was investigated in three studies using a bogus food test. Studies of food intake compared inhibitory control with other concepts of executive control. Jansen and colleagues (2009) studied the role of inhibitory control in those who were considered to be high-restrained eaters as measured by the Restrain Scale. Dietary restraint is often found in dieters. Those who are dieting are thought more often than not to overeat due to disinhibition, leading to a failure in attempts at weight loss. Often this loss of self-control can be induced experimentally and *in vivo* in response to influences such as emotional distress, intoxication or a pre-load of food (Heatherton, Polivy, & Herman, 1990). The study found that highly restraint eaters would only overeat in response to a pre-load if they were also highly impulsive (determined by a median split, SSRT 171.2). There is no agreed value for what is the expected value for defining impulsivity using the SSRT. Guerrieri and colleagues (2007) using a slightly lesser median split of 159.4, found that there was no difference in food intake between high and low-impulsiveness in a group of adult females.

Hofmann and colleagues (2008) studied the interaction inhibitory control plays between attention and affect regulation on automatic affective reactions when consuming candy. The underlying principle being impulses are assumed to contain an affective, hedonic component (Metcalfe & Mischel, 1999) and affect regulation represents the down-regulation of the hedonic affect contributing to the impulse control. It is thought that individuals who can spontaneously down regulate their affect linked to certain foods may be less prone to impulsive eating behaviours.

Attention was measured using a simple arithmetic common operation span task and affect regulation was measured by using a modification of the Affect Misattribution Procedure (AMP; Payne et al., 2005). In this task, a non-food related positive or negative stimulus was presented before a neutral Chinese pictograph. One would expect more positive judgement results of the pictograms when Chinese targets characters were preceded by positive primes. The difference in individual evaluation between the positive and negative primes is used as an indicator of affective reactivity to these stimuli. In order to access the temporal decay of affect regulation, a delay between the prime and neutral pictograph varied between the standard 100ms to at 1000 ms. The down regulation of affective reactions over time was measured by the difference in affective reactivity between positive and negative prime trials. A regression using the net candy consumption as the dependent variable found that, for those who scored low in inhibitory control, affective reactions played a larger impact on candy consumption.

3.3.4 Inducing impulsivity using inhibitory control tasks

The relationship between obesity and impulsivity are associations inferred through correlations. The process of inducing impulsivity attempts to prove causality. Houlben and colleagues (2011) demonstrated reduction in food intake following the priming of inhibitory control compared to a group primed to be impulsive. The authors paired food related cues with the stop and go-trials of the Stop Signal Task, in order to manipulate food intake during a bogus food task. In the inhibitory control manipulation, one type of food would consistently be paired with a stop signal therefore responses to this type of food would have to be consciously inhibited by the participant. In the impulsivity manipulation, one type of food would never be accompanied by a stop signal and therefore would always be reacted to impulsively by the participant. In the control arm, foods were presented with the stop signal only during half the trials. The three different foods would then be offered to the participants for tasting to determine the total food consumption. Three key findings from this study were that inhibitory manipulation reduced food intake in a group of participants known to have low inhibitory control (higher impulsiveness) at baseline to levels similar to participants with high inhibitory control. Similarly, for those with the good inhibitory control at baseline, impulsivity manipulation increased consumption of the go-food to the level of those with low inhibitory control. Guerrieri (2009) also induced impulsivity using the SST in dieters and non-dieters; sub-divided into those with high and low restraint. Results of the induction of impulsivity and inhibition were in the expected direction with regard to food intake. However, in participants who claimed to be current dieters on the day of testing showed the opposite relationship between their induced state of impulsivity and food intake based on their restraint status. As one would expect current dieters scored higher in restraint than non-dieters. Unexpectedly current dieters in the impulsivity condition had a significantly lower caloric intake compared to the current dieters in the inhibition condition. Once again the finding that current dieters increased their caloric intake in response to the inhibition induction supports the ego-depletion model of self-control. The current dieters were already engaging their self-control on their diet and are likely to be in a state of cognitive depletion. Therefore, further acts of self-control would have overwhelmed their system, leading to disinhibition. On the other hand, in the impulsivity induction there was no need to use any cognitive restraint and these participants still maintained their self-control when faced with tasty treats.

3.3.5 Inhibitory Control as a predictor of weight change.

The Stop Signal Task has been shown to be a predictor of weight change in both adolescents and adult females. In a study of normal weight female adults, those who were found to have an implicit preference for snack foods, as ascertained by an Implicit Association Task; the SSRT was shown to be a predictor of weight loss at one-year follow-up. Those adults with poorer inhibitory control lost less weight at follow-up (Nederkoorn, 2010). The authors found the same relationship in obese adolescents attending a 1-year residential weight camp programme using a simple correlation of the SSRT against the percentage reduction in BMI (Nederkoorn, 2006).

3.3.6 Inhibitory control and the intention-behaviour gap

If healthy weight related intentions are to have a direct impact on health and weight, they must be successfully translated into action. This deficit between our good intentions and actions is termed the intention-behaviour gap (Allan, 2008*)*. Fewer than a quarter of people who embark on a healthy eating plan are still sticking to it 12 months later (Dansinger, Gleason, Griffith, Selker & Schaefer, 2005). Allan and colleagues (2010) studied the role of inhibitory control using both the Go No-Go task and Stroop task in predicting the intention-behaviour gap for two key dietary behaviours: eating fruit and vegetables, and high calories snacks. A group of 50 university students quantified their intentions for these behaviours and then kept computer diaries to actually report their behaviour over a 24 hour period. It was found that the number of snacks consumed correlated significantly with performance on the Stroop Task. Therefore, those with weaker inhibition had a larger intention-behaviour gap for snacks than those with stronger inhibition.

3.3.7 Discussion

The available evidence supports the contributory role of executive function in the aetiology of obesity. The reviewed findings showing the association between behavioural measures of impulsivity and obesity may not be likely to be representative of the population as experimental groups are often students of normal weight, female or adolescents. The adolescent population is a tentative population as the level of impulsivity as a whole is rapidly changing. The prevelance of obesity between men and women are thought to be equal, however, 8% of women are thought to be morbidly obese in comparison to only 4% of men (National Health and Nutrition Examination Survey, 2013). Women are more likely to seek weight loss treatment on their own or be more likely to be referred by a physician for weight loss management than men (Thande, Hurstak, Sciacca, & Giardina, 2009) which is likely to explain the large number of groups using this population for their studies. However, one must err on the side of caution with extrapolating findings from normal weight women to obese individuals. As there has been shown to be a difference between normal weight and obese females using a temporal discounting task (Weller, Cook, Avsar, & Cox, 2008).

The development of tasks to specifically study eating behaviour has led to studies integrating food related constructs with impulsivity. An example of this is the combination of the motivation for food into the Stroop resulting in the Food Stroop (Ogden & Greville, 1993). The Food Stroop is able to predict weight change and differentiate weight loss maintainers from an obese group of participants unable to maintain weight loss. However, the task performance does not correlate with current BMI. This is a trend seen with most measures of inhibitory control. Despite being able to differentiate between obese and non-obese groups, there was no correlation between the task performance and BMI. The sample size of studies may account for this finding. These findings could also be due to inhibitory control being important in maintenance when individuals consciously try to maintain weight (hence why self control becomes important), while bmi does not indicate who is trying and who is not.

All three of the tests used in the studies identified in this review claim to measure inhibitory control. The stop signal reaction time is calculated by the latency in the stop signal delay (time between the go and stop signal) and the mean reaction time for correct go trials. Therefore, individuals who are able to wait for a delayed stop signal and respond faster to correct go-trials will have a lower SSRT time and therefore have better inhibitory control. This concept seems to capture response inhibition directly. Whilst parameters used from the go no-go task test singular measures that tap a similar construct, with a varying relationship with maladaptive eating behaviours. For example, Hall and colleagues (2012) has shown a significant effect linked to the go reaction time. However, the go reaction time is unlikely to capture inhibitory control and it is more likely to be an indicator of attention or alertness.

Chapter 4 Methodology

Due to the multi-faceted nature of impulsivity, it is necessary to capture the various constructs that lead to impulsive behaviours. Firstly, it would be necessary to measure both trait and state levels of impulsivity as actions stemming from both concepts may lead to weight gain. Personality traits are best captured by questionnaires whereas behavioural tasks manage to capture the current psyche. In order to measure both trait and state aspects of impulsivity, behavioural tasks will be supplemented with a personality inventory.

4.1 Choice of Questionnaires

The Temperament and Character Inventory (TCI; Cloninger, 1999) was chosen as it has the greatest number of subscales and as the number of measured factors increases in a given instrument, the cumulative proportion of shared variance is likely to increase between alternative models hence elucidating any associations that would otherwise be missed. The TCI is a global measure of personality with an underlying neuronal pathways associated with each of the subscales. Brain PET imaging studies of the Behavioural Activation System have identified mesolimbic dopaminergic pathways (Cloninger, 1999). Harm Avoidance in particular was significantly correlated with to brainstem, cerebellum and the right temporal cortex ($r=0.5$, $p<0.01$). Similarly quantitative genetic studies showed scores of the temperament dimensions were heritable (54-61% stable variation in trait). The TCI will be supplemented with the Barratt Impulsivity Scale (BIS) as this is the most commonly used personality inventory.

4.2 Choice of Behavioural Tasks

From the systematic review, the SST was found to be the most reliable behavioural measure recorded in obesity research. It is a measure of short term to immediate impulsive control. Therefore, Temporal Discounting will also be utilised as a measure of longer-term impulsive control. The SST yielded the most positive results in obese participants, being able to differentiate being able to differentiate between obese and normal weight individuals. It als also been used successfully in adolescent groups making it the most suitable inhibitory control task. Inhibitory control is also an instantaneous response to either an internal or external cue. In order to complement the SST the Temporal Discounting Task was used to measure long term value of rewards. Monetary Temporal Discounting was used as opposed to health choices as the younger participants are more likely to understand the value of money.

4.3 What the study adds to the existing literature

This will be the largest study to correlate BMI with behavioural measure so, impulsivity. Furthermore, the study will test impulsivity as a predictor of weight reduction in subjects seeking a wide range of weight management alternatives. The variety of subjects included in the study will help determine if there is any phenotypical difference between the groups, which may have implications for successful weight reduction. A pragmatic experimental approach also means that any findings are more likely to be applicable to a population seeking weight management. In addition to measuring impulsivity, the study pilots two interventions targeting impulsive behaviours making it novel from existing published research in the field of impulsivity and obesity.

4.4 Patient Groups and Research Access

4.4.1 Adolescents

The adolescent group was recruited with parental consent from the MoreLife residential camp in the United Kingdom, over a two-year period (Summer 2011 and 2012). Ethics was granted from Leeds Metropolitan University Ethics committee. Testing was undertaken during fixed periods of 1.5 hours often during breaks or screen time. Three students were tested during each session. The control group was an age-matched cohort of secondary school children of normal weight (Table 4-1, 4-2).

4.4.2 Adults

The first comparator group was recruited from the bariatric patients referred to Imperial College Weight Management Centre for Surgery. Ethics was granted from the North West Thames NHS Trust Committee. Individuals were tested during their attendance to a specialist clinical psychologist organized for pre-operative assessment. The second comparator group was recruited from a community lifestyle intervention in Essex, organized by MoreLife. Ethics was granted from Imperial College London Ethics Committee. Participants were tested prior to attending their weekly therapy within the first 3 three weeks of a 12 week intervention. Both groups were compared to a control group of normal weight adults recruited from Imperial College London. The following table (Table 4-1) illustrates the groups tested for impulsivity measures.

Table 4-1 Table illustrating the groups tested for impulsivity measures

	ADULTS	ADOLESCENTS
COMPARATORS- OBESE	ICL BARIATRIC PATIENTS MORELIFE COMMUNITY	MORELIFE RESIDENTIAL
CONTROLS- NORMAL WEIGHT	ICL STUDENTS	SECONDARY SCHOOL

Table 4-2 Table illustrating the setting, intervention type and duration of each of the interventions. When pooling the results in chapter 5 the following groups were added (Adolescent School, Adolescent Residentail Camp, Adult Community Obese, Adults Hospital Obese and Adult Community Control). The Adolescent Community Obese were a follow-up of the residential group.

		N	Intervention type	Intervention duration	Additional information
Control	School	53	None	None	Pre and Post
Obese	camp	50	Lifestyle	3-8 weeks	
Obese	Community	27	Lifestyle- SMS and voice messages	12 weeks	
Adults					
Control	Community	40	Control group	None	
Obese	Hospital	40	Surgery	1 year	Pilot study- BIS only
Obese	Hospital	43	Surgery	6 month	
Obese	Community	20	Lifestyle	None	

4.5 Selection of Research Tools

4.5.1 Behavioural measures.

Neurobehavioural measures are a potential intermediary tool to study a particular behaviour or psychological construct such as impulsivity, which can be associated with specific brain regions or pathways. Research in neuroscience using functional neuroimaging (Batterink, Yokum, & Stice, 2010; Killgore & Yurgelun-Todd, 2005; Martin et al., 2010; Wang et al., 2001), electrophysiology (Nijs, Muris, Euser, & Franken, 2010; Silva, Pizzagalli, Larson, Jackson, & Davidson, 2002), non-invasive brain stimulation (Camus et al., 2009; Fregni et al., 2008; Uher et al., 2005), hormonal manipulation (Batterham et al., 2007; Farooqi et al., 2007; Malik, McGlone, Bedrossian, & Dagher, 2008) and genetics (Stice, Yokum, Blum, & Bohon, 2010) has begun to find neurobiological substrates of these constructs. For example, self-control may be represented by both the Stop Signal Task and a questionnaire measurement of Novelty Seeking. These measures have both been linked to maladaptive eating behaviours (Bogg & Roberts, 2004; Nederkoorn, Smulders, Havermans, Roefs, & Jansen, 2006) and related structurally to the prefrontal cortex. The behavioural methods chosen from the review of literature identified three tests of executive function related to obesity. The Stop Signal Task and the Stroop Task seem to have the most consistent relationship with BMI and eating behaviour with 80% of measurements showing a significant relationship in a recent review (Vainik, Dagher, Dube, & Fellows, 2013). The third measure of impulsivity that has shown relationship with obesity in population based studies and certain subsets of patients is the Temporal Discounting Task. The Stop Signal Task and the Temporal Discounting Task were selected as the preferred behavioural measures as they both assess choice or decision architecture at different points in time. The Stop Signal Task is a measure of immediate stopping impulsivity whereas the Temporal Discounting Task captures a more long term waiting impulsivity.

4.5.1.1 Stop Signal Task.

The CANTAB (Cambridge, UK; Cambridge Cognition) Stop Signal Task used was adapted from that employed by Logan and colleagues (1996) and was used to measure inhibitory control to a pre-potent motor response. These tests have been validated by a number of studies and in different patient groups (Elliott, McKenna, Robbins, & Sahakian, 1995; Owen, Iddon, Hodges, Summers, & Robbins, 1997; Rahman, Sahakian, Hodges, Rogers, & Robbins, 1999) as well as demonstrating a high degree of sensitivity to changes in cognitive functioning resulting from neurochemical manipulations (Coull, Middleton, Robbins, & Sahakian, 1995; Mehta, Sahakian, McKenna, & Robbins, 1999). The experimental task contained two components: the go task and the stop task. The stimulus for the go-task were arrows pointing either to the left or right of a computer monitor for 1000ms. Participants were instructed to make a speeded response to targets in the go task by pressing the corresponding key on a controller with their index and middle finger. The stop task required subjects to inhibit responses to the stimulus to the go task when a stop signal appeared. The stop signal was an audible sound delayed after the go stimulus. The initial stop signal delay was set at 250ms and then adjusted dynamically dependent on the subject's behaviour. The stop signal reaction time (SSRT) measures the time needed to cancel a go response following an audible stop stimulus and it is an indicator of inhibitory control. Participants were placed in a quiet room with no background noise of disturbances. A single researcher was present during the task to give instructions and answer any queries.

4.5.1.2 Temporal Discounting Task.

A monetary Temporal Discounting Task was delivered using validated purpose written software in MATLAB Version 7.10.0 and Cogent 2000 (Natwick, Massachusetts, The Mathworks Inc.). Participants were sat in identical surroundings to the Stop Signal Task. A computer using a choice algorithm controlled all trial presentations (Rubinstein, 2007). A Revealed Preference method estimated measures of intertemporal discounting. Participants were presented with two labels on either side of the monitor: a sooner and shorter monetary reward on one side (e.g., £5 now), and a larger delayed reward on the other (e.g., £50 in 5 weeks).

The text would remain on the screen for 0.5 seconds during which time any response would be ineffective. Pressing the corresponding left or right arrow key made the preferred choice. Participants were specifically told that there was no time limit to the task, there was no correct or incorrect answer and these were one-off payments with no need to make any calculations. Choices were made for real monetary rewards with a total of 240 monetary options. The discounting parameter k was recorded as an index of the rate at which the participants depreciate rewards as a function of time, according to the formula: $V=A/(1+kD)$, where V is the present value of the delayed reward A, at delay D, and k is the discount rate (Kable & Glimcher, 2007). A high k value is an indicator of greater impulsivity.

4.5.2 Personality Questionnaires

The Barratt's Impulsivity Scale (BIS) was selected as it is the most widely used self-report measure of personality traits (Patton, Stanford & Barratt, 1995) and it captures impulsivity as a broad component. The second questionnaire to be used was the TCI Cloninger, 1987). Compared to lean subjects, obese subjects in the community scored higher in Novelty Seeking, lower in Persistence and lower in Self directedness. Furthermore, the Novelty Seeking component of the questionnaire was able to predict patients who lost weight during a lifestyle intervention (Sullivan, Cloninger, Przybeck, & Klein, 2007). The TCI was also chosen as the Novelty Seeking subscale correlates well with the five factor model trait of extraversion, Sensation Seeking from Zuckerman's alternative five model of personality and with Psychotism in Eysenck's model (Ball, Tennen & Kranzler, 1999; Zuckerman, Cloninger, 1996).

4.5.2.1 Barratt Impulsivity Scale

The Barratt Impulsivity Scale (Patton, Stanford, & Barratt, 1995) is a questionnaire designed to assess the personality and behavioural construct of impulsiveness. The BIS was devised by Barratt as he was convinced that impulsivity was not a uni-dimensional construct and was an orthogonal trait to anxiety. This was supported by several factor analyses reviews at the time (Barratt, 1965; Eysenck & Eysenck, 1977; Twain, 1957). The BIS aimed to measure impulsivity as a solitary trait in itself, separate from other action oriented traits described by past models (Sensation Seeking, Extraversion and Risk Taking). Barratt initially described three subtraits in the 10th version: Attentional Impulsiveness which involves making quick decisions, Motor Impulsiveness which involves acting without thinking, and Non-planning Impulsiveness which involved a lack of forethought (Barratt, 1985). A principle component analysis of the BIS-10 collected from 412 university students was used to specify the impulsivity components further. The principle component analysis identified six first order factors: Attention, Motor, Self-control, Cognitive Complexity, Perseverance and Cognitive Instability. Examples of questionnaire for each of the components are illustrated in the table below (Table 5.1). The BIS-11 has an internal consistency of 0.83 (Cronbach's α) for the total score and test-retest reliability at one month of 0.83 (Spearman's Rho). The second order factor motor component (11 items) has an internal consistency of 0.59 and a test-retest reliability of 0.67. For the first order subscales, the motor component (7 items) has an internal consistency of 0.64 and test-retest reliability 0.67. Self-control has an internal consistency of 0.72 and test-retest reliability at one month of 0.73 (Barratt, 1985).

Table 4-3 Subtraits of the BIS and examples of questions (* reverse score items)

2nd Order Factors	1st Order Factors	No of items	Items contributing to each subscale
Attentional	Attention	5	*I don't pay attention* *I am restless at plays or lectures*
	Cognitive Instability	3	*I have racing thoughts* *I change hobbies* *I often have extraneous thought when thinking*
Motor	Motor	7	*I do things without thinking* *I make up my mind quickly* *I am happy-go-lucky* *I act on impulse* *I act on the spur of the moment*
	Perseverance	4	*I change jobs* *I change residences* *I can only think about one problem at a time* *I am future orientated*
Non-Planning	Self-Control	6	*I plan tasks carefully** *I plan trips well ahead of time** *I am self-controlled** *I am a careful thinker**
	Cognitive Complexity	5	*I get easily bored when solving thought problems* *I am more interested in the present than the future* *I like puzzles*

4.5.2.2 Cloninger's Temperament and Character Inventory

The Temperament and Character Inventory measures seven dimensions of personality (1987). There are four dimensions of Temperament: Novelty Seeking, Reward Responsiveness, Harm Avoidance and Persistence, and three dimensions of character: Self-directedness, Self-transcendence and Cooperativeness (see Table 5.2). Each dimension has a unique genetic variance and is reproducible in clinical and general populations. Temperaments are aspects of emotional responses and are stable through time whereas characters are styles of mental self-government and may develop or mature through time with experience. The questionnaire is composed of a series of true/false questions about the test takers likes and dislikes, emotional reactions, interests, attitudes, goals and values which is then scored to assess the different dimensions of personality. Each of the seven dimensions is uniquely heritable and associated with specific neurotransmitter genes and regional brain activity (Cloninger, 1987). Cloninger and colleagues (1993) calculated the internal consistency of the questionnaire on a sample of community volunteers. Internal consistency for the temperament domain scales ranged from 0.65 to 0.87 and 0.84 to 0.89 for the character domain scales.

Table 4-4 Domains of the TCI with examples

Domain	High Scores	Low Scores	Example
Temperament			
Harm Avoidance	Anticipatory Worry and Pessimism	Uninhibited optimism	*I usually am confident that everything will go well, even in situations that worry most people*
	Fear of uncertainty	Bold and confident	*I often feel tense and worried in unfamiliar situations, even when other feel there is little to worry about.*
	Shy with strangers	Outgoing	*I often avoid meeting strangers because I lack confidence with people I do not know*
	Fatiguable	Vigorous	*I have less energy and get tired more quickly than most people.*
Novelty Seeking	Exploratory and curious	Indifferent/stoic rigidity	*I often try new things just for fun or thrills, even if most people think it is a waste of time*
	Impulsive	Reflective	*I often do things based on how I feel at the moment without thinking about how they were done in the past*
	Extravagant and Enthusiastic	Frugal and detached	*I am much more reserved and controlled than most people*
	Disorderly	Orderly and regimented	*I like it when people can do whatever they want without strict rules and regulations*
Reward dependence	Sentimental and warm	Practical and cold	*I like to please other people as much as I can*
	Openness to warm communication	Aloofness	*I am good at communicating my feelings to others*
	Dedicated and attached	Withdrawn and detached	*I like to discuss my experiences and feelings openly with friends instead of*

			keeping them to myself
	Dependent	Independent	*I usually do things my own way- rather than giving into the wishes of other people*
Persistence	Industrious and diligent	Inactive and indolent	*I am usually eager to get going on nay job I have to do.*
	Work hardened	Spoiled	*I like a challenge better than easy jobs*
	Ambitious and overachiever	Modest and underachiever	*I am a very ambitious person.*
	Perseverant and perfectionist	Quitting and pragmatic	*I am usually so determined that I continue to work long after other people have given up*
Character			
Self-Directedness	Responsible and reliable	Blaming and unreliable	*I often feel I am the victim of circumstances*
	Purposeful	Purposeless	*Often I feel that my life has little purpose or meaning.*
	Resourceful and effective	Inert and ineffective	*I often wait for someone else to provide a solution to my problem*
	Self-accepted	Self-striving	*I often wish that I was smarter than everyone else.*
	Enlightened second nature	Bad habits	*I have may bad habits that I wish I could break.*
Cooperativeness	Social acceptance	Social intolerance	*I can usually accept other people as they are, even when they are very different from me.*
	Empathy	Social disinterest	*I don't seem to understand most people very well.*
	Helpfulness	Unhelpfulness	*I like to help find a solution to problems so that everyone comes out ahead.*
	Compassion	Revengefulness	*When someone hurts me in anyway, I usually try to get even.*

	Pure-hearted Conscience	Self-serving Advantage	*I would do almost anything legal in order to become rich and famous, even if I would lose the trust of many old friends.*
Self-Transcendence	Self-forgetful	Self-conscious experience	*Often I have unexpected flashes of insight or understanding while relaxing.*
	Transpersonal Identification	Self-Differentiation	*I usually feel a strong sense of unity with all the things around me.*
	Spiritual Acceptance	Rational Materialism	*I think that most things that are called miracles are just chance.*

The table below (Table 4-5) summarises the tests performed in each of the groups that participate in the study.

Table 4-5 – Tests performed in each group

Tests	**Obese Adolescents**	**Normal Weight Adolescents-**	**Obese Adults-Bariatric Surgery**	**Obese Adults-Lifestyle Intervention**	**Normal Weight Adult**
Behavioural					
SST	×	×	×	×	×
TDT	×	×	×	×	×
CGT			×	×	
Questionnaires					
TCI- Adult			×	×	×
TCI- Junior	×	×			
BIS			×	×	×

SST – Stop Signal Task **CGT** - Cambridge Gambling Task

TDT – Temporal Discounting Task **TCI** - Temperament and Character Inventory

ALT – Associative Learning Task **BIS** – Barratt's Impulsivity Scale

4.6 Aims

4.6.1 Primary Aim

4.6.1.1 Diagnostic validity

1. Whether impulsivity can predict difference in BMI between normal weight and obese participants.

4.6.2 Secondary Aims

4.6.2.1 Prognostic validity

1. Can impulsivity be used as a predictor of weight loss?

4.6.2.2 Explanatory validity

1. Can impulsivity be modified?
2. Can neurocognitive agents reduce impulsivity?
3. Can an intervention targeting impulsivity maintain weight reduction?

Chapter 5 Diagnostic validity of impulsivity measures: A correlation of impulsivity measures in four subject groups.

5.1 Introduction

5.1.1 Impulsivity in the normal population

To date most studies based on impulsivity have focused on adults with personality disorders, externalising psychiatric disorders (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001; Moeller et al., 2002) or high risk groups, such as adolescents (Winstanley, Eagle, & Robbins, 2006). The measurement of impulsivity in obese participants actively seeking weight management against a normal healthy weight subgroup will help to validate the use of the chosen measurement tools of impulsivity and delineate the construct further. The National Institute on Alcohol Abuse and Alcoholism NESCAR survey is the first to study trends in impulsivity in the general population (Chamorro et al., 2012) (see Table 6-1). In a face-to-face survey of 34, 653 adults aged over 18 year old residing in continental United States of America, it was shown that the lifetime prevalence of self-reported impulsivity in the general population is 16.9% (Confidence Interval(CI)=16.4-17.5%). The measure of impulsivity was the question '*Most of the times through out your life, regardless of the situation or whom you were with, have you ever done things impulsively?'*. The question was placed in the borderline personality disorder section of the survey. Impulsivity was correlated with psychiatric disorders, questions regarding behaviours associated with disinhibition, psychsocial functioning and adverse events potentially associated with impulsivity (diagnosis of a sexually transmitted disease, starting fights, reckless driving). The study found men to be more impulsive than women (Odds Ratio (OR)=1.38, CI=1.28-1.48). This finding in the general population is also supported by neurobiological and questionnaire based studies of cognitive style and social expectation (Calvete & Cardenoso, 2005; Manuck et al., 1999). Impulsivity was found to be more common in individuals with high school or lower educational attainment than among individuals with at least some college education. On average, impulsivity was also less common in an individual with an income over $35,000 than in individuals with an income below $19,000. Those found to be more impulsive were also more likely to have never married, been divorced or to be in a younger cohort (ages 18-29). Amongst unfavourable behaviours, 'engaging in quick sexual relationship without thinking about the consequences' had a prevalence of 33.79% (95% CI=2.37-35.24%) among individuals with impulsivity versus 10.64% (CI=10.15-11.16%) amongst those without. The behaviours most strongly associated with impulsivity were: having problems with gambling or spending too much money; and having sudden changes in personal goals, career plans and other important aspects of life (Adjusted Odds Ratio (AOR) =3.58, CI=3.22-3.97). Individuals with impulsivity were more likely to have a lifetime history of at least one psychiatric disorder and more likely to engage in behaviours that could be dangerous to themselves or others, such as starting fights (AOR =3.53, CI=2.03-6.14) and shop lifting (AOR=2.77, CI=1.83-4.20). Therefore, impulsivity ascertained by a single question is able to predict much high-risk behaviour within the general population. However, the BMI of participants was not recorded in this study.

Table 5-1 Key associations from a population wide study of impulsivity

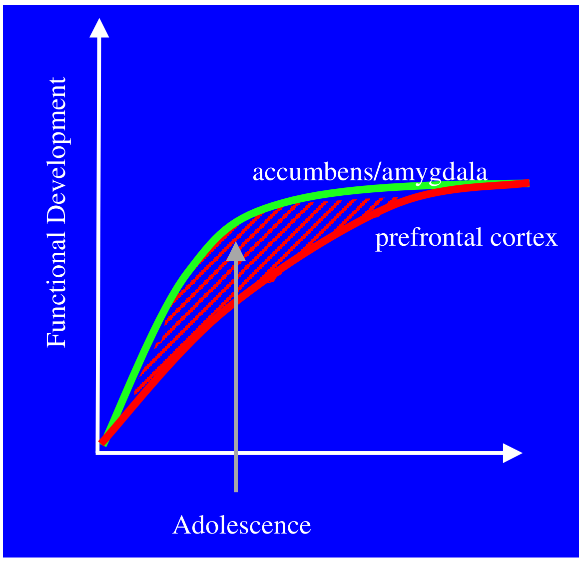
Impulsivity in the General Population
F<M
Less educate
Never married/divorced
Younger (18-29)
High risk behaviours
Psychiatric disorders

5.1.2 Development of impulsivity

Impulsivity develops with age (Paulsen & Johnson, 1980; Steinberg, 2010), thought to peak at adolescence and decreasing there after with the development of cognitive functioning associated with the maturation of the prefrontal cortex (Galvan et al., 2006; Gogtay et al., 2004). Modern accounts of teenage impulsiveness propose that it stems from an imbalance between two interconnected brain networks: the *incentive processing system*, which is active when we anticipate and process rewards and punishment, as well as the emotional/social processing, and the *cognitive control system*, which is associated with logical reasoning and impulse regulation (Steinberg, 2008). The incentive processing system begins to develop rapidly with the onset of puberty causing teenagers to be more attentive towards rewards with resultant sensation seeking behaviour (Ernst et al., 2005). In contrast the cognitive control system has a much slower developmental rate which continues well into the twenties (Steinberg, 2004). The mid-adolescence in particular (age 14-17) is a particularly vulnerable period when the disparity between the two systems is largest. 'The peer effect' makes impulsivity in adolescents situational. Steinberg (2004) reported that adolescents with peers watching were more likely to run a yellow light and risk a car crash during a simulated driving task.

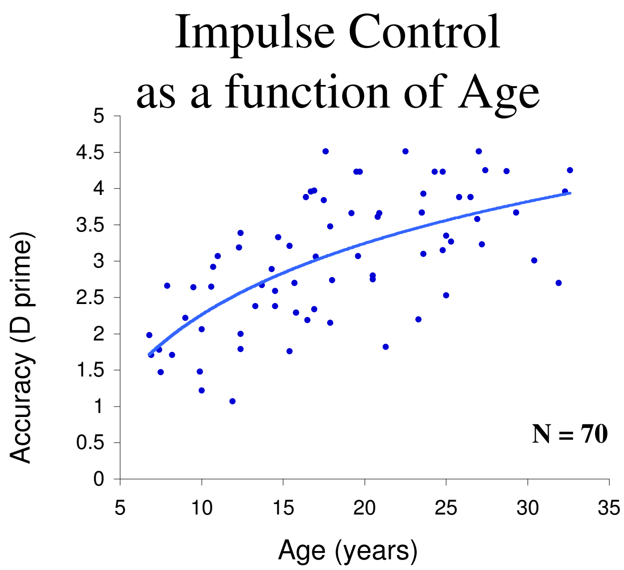
Figure 5-1 represents a line graph illustrating the differential development of two interrelated brain pathways during adolescents. The pre frontal cortex which is involved in top-down control is slower than the more emotional part (amygdala and accumbens) leading to an increase of impulsive behaviour during adolescence. Modified from Casey, Getz & Galvan (2008).

Figure 5-1 A graph illustrating the differential development of two interrelated brain pathways



The figure below (Figure 5-2) represents the impulse control as function of age and is modified from Hare and colleagues (2007) study that recorded 70 individuals of different age groups and shown how impulsivity develops well into early adulthood.

Figure 5-2



To better understand the relationship among BMI, age, gender and impulsivity we sought to characterise a heterogeneous population on these constructs in a cross-sectional study. In recognition that impulsivity is not uni-dimensional, it was assessed using four validated tools. Two behavioural: the Stop Signal Task (SST) and a monetary temporal discounting task, and two self-report questionnaires: the Barratt Impulsivity Scale (BIS) and the Temperament and Character Inventory (TCI).

5.1.3 Normative Data

5.1.3.1 SSRT

To date there is no normative data available for impulsivity as measured using the SSRT. Therefore, norms have been collected from different studies. Nederkoorn has published SSRT values on normal weight and obese women and adolescents (See Table 5-2).

Table 5--2 Normative data for SSRT

Authors	Study Group	Number	Age	SSRT values
Nederkoorn (2004)	Normal weight undergraduate females	63	19	Low restraint (161.6, SE 5.4) High restraint (184.3, SE 4.9)
Nederkoorn (2006)	Obese and normal weight females	39 (BMI 39)	40.9	Normal weight women (170-235) Obese women (190-218)
Nederkoorn (2006)	Obese Adolescents	26 children (16 Male, 9 Females)	9.3 (SD 1.2)	236.9 (74.8)

5.1.3.2 Barratt Impulsivity Scale (BIS)

In a cross-sectional study of the healthy normal population (n=700, 418 females, 279 males) a linear regression of demographic variable predicting the total score of the BIS was significant, F (3,695)=26.8, p<0.101. The model accounted for 10% of the variance. Males scored higher than females, and scores tended to decrease with age and education. A one-sample Kolmogorov-Smirnov Test indicated that scores were normally distributed (Z-1.02, p=0.249, two tailed significance) (Spinella, 2007).

5.1.3.3 Temperament and Character Inventory (TCI)

Cloninger published normative data for his questionnaire and found that females tended to have higher Harm Avoidance scores, higher Reward Dependence scores and lower Novelty Seeking scores than males. He also reported that two studies to date have tested the reliability of the TCI in a representative English sample. Otter and colleagues (1995) tested the reliability of the TCI in a sample of 413 English males and females. In addition to making comparisons between personality traits, comparisons were made between the personality scores obtained by the English sample and the US normative data produced by Cloninger (1991). They found that scores from each of the subscale were approximately normally distributed. English subjects were found to have consistently higher mean total Novelty Seeking scores than the US. However, this may have been of an age difference between the two groups. Cloninger suggests that, with increasing age there is a tendency for Novelty Seeking and Reward Dependency to decrease, but Harm Avoidance to increase. DeLorme (2012) found that all of the TCI scales were normally distributed in a sample of 891 university students. Females scored higher on Harm Avoidance and and Reward Dependence subscales but there was no overall gender difference in the Novely Seeking subscale.

5.2 Methods

5.2.1 Measurement of impulsivity

Methods for testing are as outlined in the Methodology Chapter.

5.2.2 Participants

Four distinct groups of participants were recruited for testing. Information regarding research access and participants can be found in the Methodology Chapter.

5.2.2.1 Adolescents

Forty-seven participants were recruited over two summer's vacations from a residential weight-loss camp in the UK. All participants were obese and referred by their General Practitioner for weight loss management. Testing was performed within the first week of attending camp with parental consent. Participants had a mean age of 14.3 (SD=1.6, range 10 to 17 years) with a BMI of 33.2 (SD 8.0). Fifty adolescents matched by age and sex were recruited from a local secondary school with a mean BMI of 20.6 and a mean age of 13.8 (SD=1.7, aged between 10 and 16 years).

5.2.2.2 Bariatric surgery group

Forty-five patients who attended a Tier IV service at the Imperial Weight Management Centre were recruited and tested prior to having surgery. Patients from the bariatric group had a BMI of 44.2 (SD=6.3) and were 43.2 (SD=13.1) years old (range 20 to 66 years-old).

5.2.2.3 Obese adults attending lifestyle intervention

Twenty obese participants attending a community lifestyle intervention were tested during their first week of attendance, with a mean BMI of 36.2 (SD=3.6) and a mean age of 39.6 (SD=7.6, range 20 to 65 years-old).

5.2.2.4 Normal weight adults

Forty university students attending Imperial College London were recruited by a college advert. Students had a BMI of 22.1 (SD=1.4) and a mean age of 23.8 (SD=2.3, range aged 19 to 32 years-old).

5.2.3 Exclusion criteria

Participants were screened by a single researcher and excluded if they were officially diagnosed with an eating disorder, ADHD, were taking neurostimulant medication or had learning or neurological difficulties.

5.2.4 Statistical Analysis

A one-way between-subjects ANOVA between subjects was conducted to determine whether there was a difference in impulsivity measures overall between the four test groups and gender differences. The impulsivity measures and BMI were normally distributed through the sample. Therefore, a parametric test was used for correlating these measures with the personality questionnaires. A linear regression model was used to determine whether measures of impulsivity or demographic variables predicted BMI.

5.3 Results

5.3.1 Stop Signal Task.

A one-way ANOVA between subject showed there was a significant effect of the five different conditions (controls, bariatric surgery, lifestyle) for measures of impulsivity (F (4,198)=169.9, p=0.005). As there was a statistically significant result from the ANOVA, a post hoc test was needed to compute the difference between each of the groups. Tests between the five groups were conducted using Bonferroni adjusted alpha level of 0.05/5= 0.01 per test. The lifestyle intervention had the lowest SSRT (M=152.9 (SD 41.4)) compared to the control group (M=157.1 (SD 38.9), p=1.0) and the bariatric group (M=185 (SD 65.3), p=0.45). However, there was no significant difference between the adult groups in inhibitory control. In the adolescent groups, obese adolescents were found to be more impulsive (M= 218.4 (SD 80.5)) than normal weight adolescents (M=153.6 (SD 48.4), p=0.0005). The normal weight adolescents were not, though, more significantly impulsive than any of the adult groups (Adult control (ΔM=-3.5 (SD=12.6), p=1.0), Adult lifestyle (ΔM=0.75 (SD 15.7), p=1.0), Bariatric (ΔM=-31.4 (SD=12.2), p=0.1). However, the obese adolescent group was significantly more impulsive using the SSRT than all adult groups except for those in the bariatric surgery group (ΔM=33.4 (SD 12.4), p=0.07) [Normal adults (ΔM=61.3 (SD=12.7), p=0.0005), Adult lifestyle (ΔM=65.6 (SD=15.8), p=0.001)].

5.3.2 Temporal Discounting Task.

The least impulsive groups on the monetary Temporal Discounting Task were once again the adult lifestyle group (0.33 (SD=0.36)) and the most impulsive were the obese adolescents (0.56 (SD=0.36)). However, there was no significant difference in temporal discounting between all four groups [F(4,197)=56.7, p=0.742].

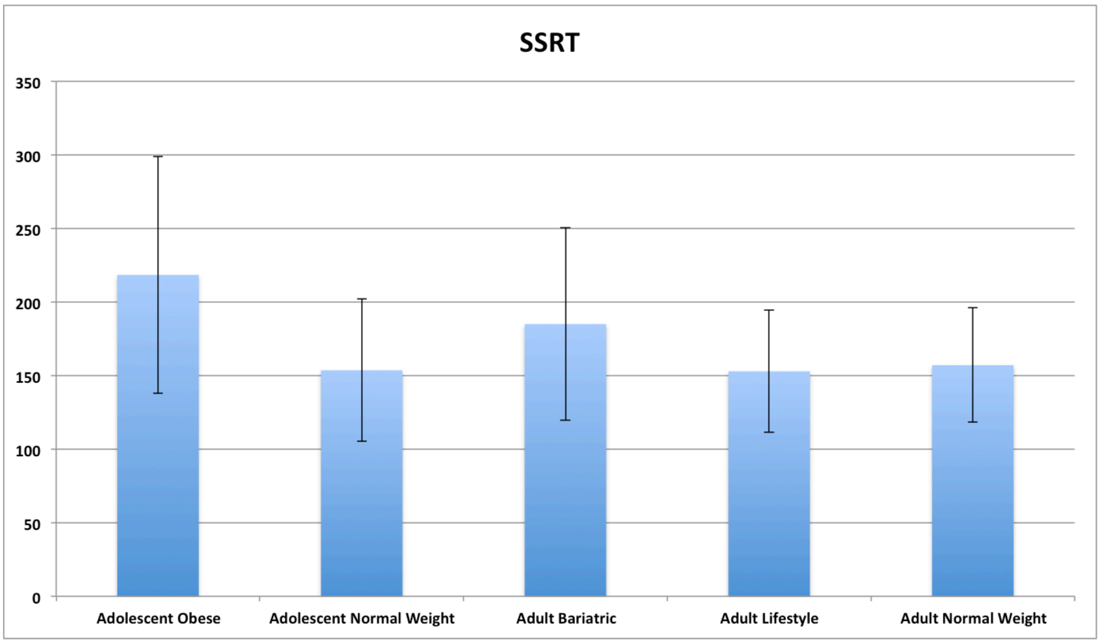
The mean differences in Age, BMI, SSRT and Temporal Discounting Constant (TDk) between groups are summarized in the table below (See Table 6-3). [* On the SSRT obese adolescents were significantly more impulsive than the lifestyle and adult control group but no the bariatric surgery group (p=0.001). Obese adolescents were also significantly more impulsive than the adolescent control group (p=0.0005)].

Table 5-3 Mean differences in age, BMI, SSRT and TDk between groups

Group	N	Sex	Age	BMI	SSRT	TDk
Adolescents						
Obese	47	M=17, F=30	14.3± 1.6 (10.0-17.0)	33.2 ± 8.0	*218.4 ± 80.5	0.56 ± 0.36
Normal Weight	50	M=27, F=23	13.8 ± 1.7 (10.0-16.0)	20.6 ± 2.1	153.6 ± 48.4	0.37 ± 0.29
Adults						
Bariatric	45	M=14, F=31	43.2 ± 13.1 (20.0-63.0)	44.2 ± 6.3	185.0 ± 65.3	0.41 ± 0.39
Lifestyle	20	M=6, F=14	39.6 ± 7.6 (20.0-65.0)	36.2 ± 3.6	152.9 ± 41.4	0.33 ± 0.36
Normal Weight	40	M=40	23.8 ± 2.3 (19.0-32.0)	22.1 ± 1.4	157.1 ± 38.9	0.40 ± 0.38

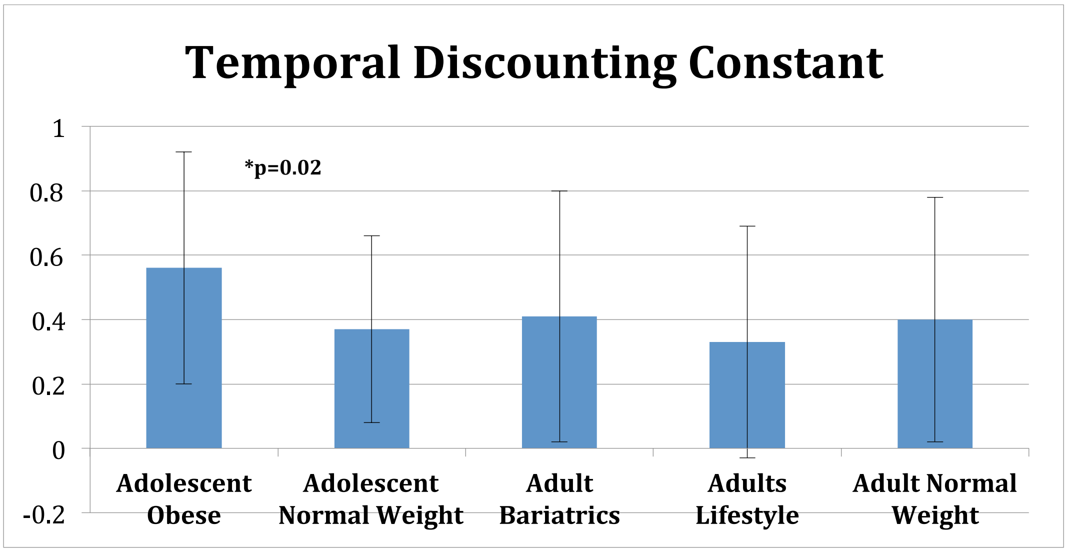
The figure below (Figure 6.3) is a column graph illustrating the difference in impulsivity between all five groups. After post hoc analysis there was found to be a significant difference between the obese and normal weight adolescent group*. The obese adolescents also had a significantly greater impulsivity score than the adult lifestyle group** and normal normal weight adults**.

Figure 5-3 Column graph illustrating the difference in impulsivity between all five groups



The figure below (Figure 5-4) is a column graph illustrating the difference in Temporal Discounting Constant (TDk) between the five groups.

Figure 5-4. Column graph illustrating the difference in Temporal Discounting between the five groups.



5.3.3 Gender and impulsivity

There was no difference in SSRT between male (M=168.0 (SD=64.1) and female (M= 185.0 (SD=63.6) participants (F (1,202)=3.6, p=0.06). Female (M=0.48 (SD=0.36) participants were found to be more impulsive than male (M= 0.38 (SD=0.35) participants when comparing the TDk (F(1,202)=4.5, p=0.04) (See Table 5-4.

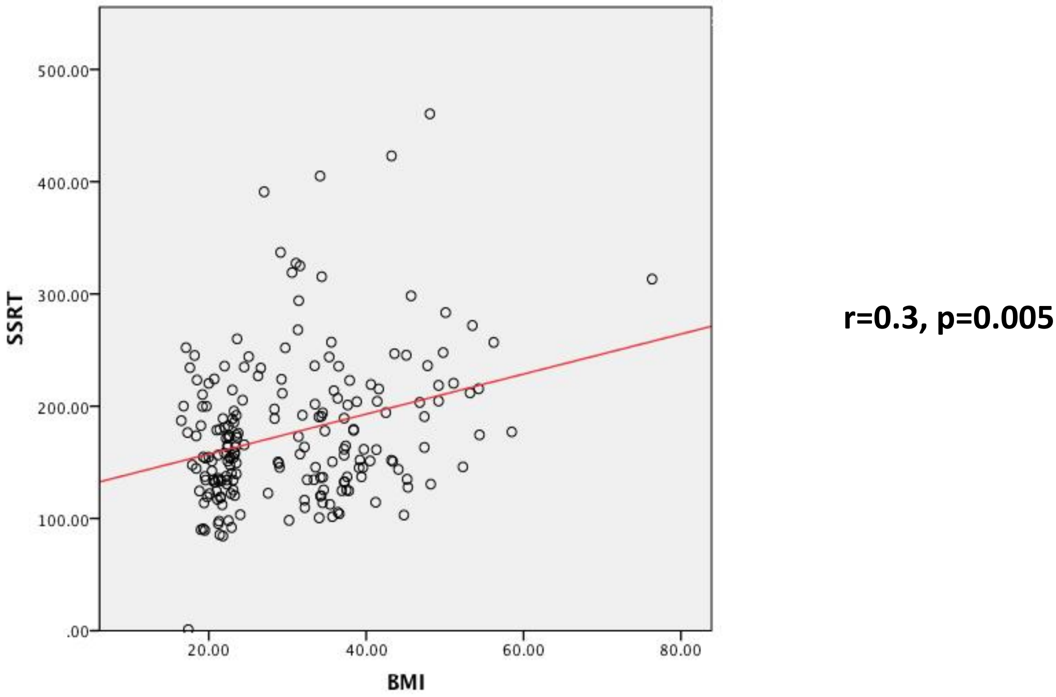
5.3.4 BMI and Behavioural Impulsivity

For further characterisation of the impulsivity across our entire sample size (n=202), all data was pooled. A linear regression with the BMI as the dependent variable and age, gender, SSRT and TDk as independent variables produced an overall significant equation (R^2=0.53, F(4,197)=56.7, p=0.0005). Age (β=0.60, p=0.0005), Sex (β=-0.2, p=0.0005) and the SSRT (β=0.3, p=0.0005) were all found to be significant predictors of BMI. The TDk did not predict significantly BMI (β=0.3, p=0.7). A correlation of the five variables as parametric data showed that the SSRT (r=-0.002, p=0.98) and TDk (r=-0.1, p=0.2) did not show a significant correlation with age. The SSRT showed a positive correlation with BMI (r=0.3, p=0.005) whilst discounting constant showed no such relationship (r=0.001, p=0.98).

Table 5-4 The difference in BMI, age and mean impulsivity measures between genders.

Sex		BMI	SSRT	Discount k	Age
Female	Mean	34.4	185.0	.48	26.6
	N	99	99	99	99
	SD	10.3	63.6	.36	15.9
Male	Mean	27.0	168.0	.38	23.6
	N	104	103	104	104
	SD	9.6	64.1	.36	12.2
Total	Mean	30.6	176.3	.43	25.0
	N	203	202	203	203
	SD	10.6	64.3	.36	14.1
Significance		0.001	0.06	0.04	0.14

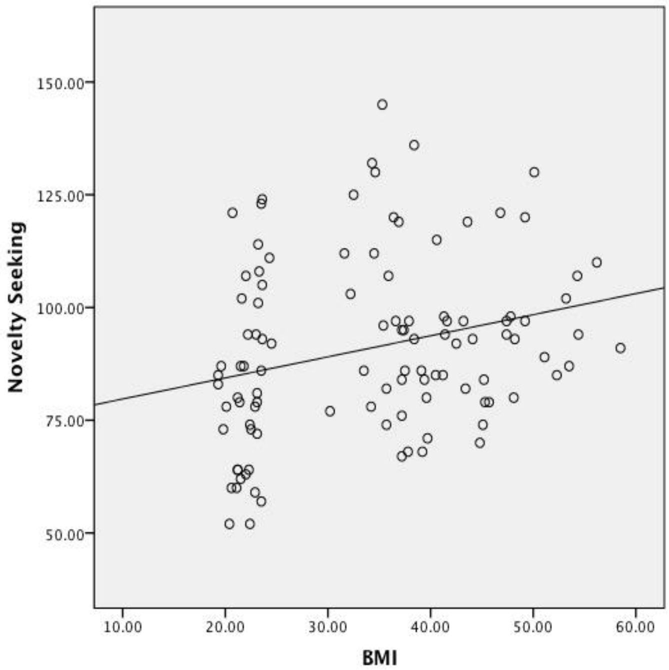
Figure 5-5 The SSRT correlated positively with the BMI



5.3.5 BMI and Personality Questionnaires

The correlation between behavioural tasks and personality questionnaire for the adolescent group is discussed fully in Chapter 7. For the adults questionnaires (n=106), all subdivisions of the BIS and the TCI-R were correlated against the SSRT and TDk. BMI correlated with Non-planning (r=0.237, p=0.014), Self-control (r=-0.4, p=0.0005) and Cognitive Complexity (r=-0.2, p=0.04) of the BIS. Novelty Seeking (r=0.3, p=0.002) and Harm Avoidance (r=0.2, p=0.02) were both significantly correlated with BMI in the TCI.

The Figure 5-6 Novelty seeking scale of the TCI correlated positively with BMI.

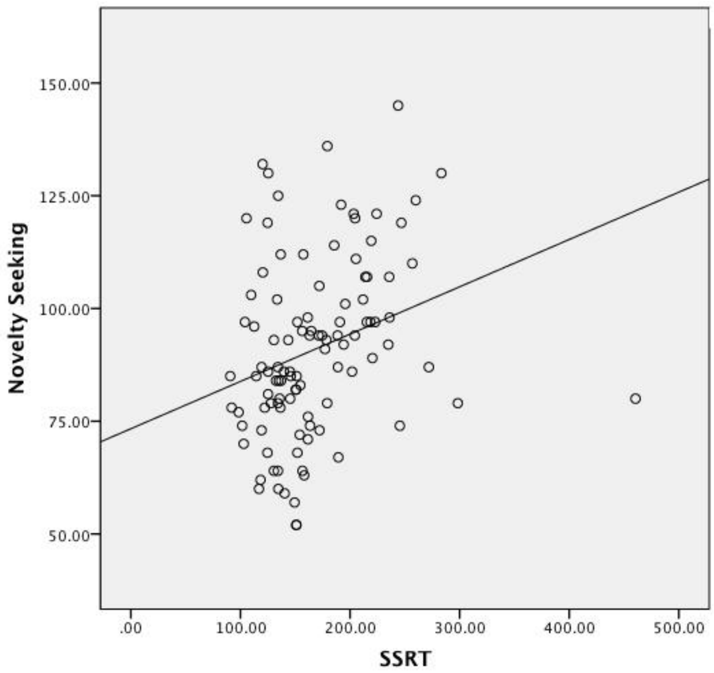


r= 0.3, p=0.002

5.3.6 SSRT and Questionnaires

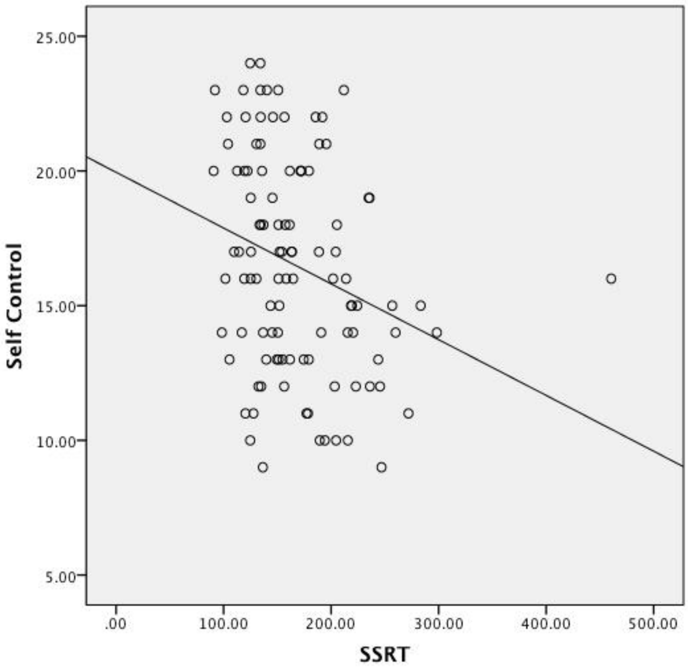
The SSRT correlated negatively with Self-control (-0.3, p=0.005) only from the BIS and correlated positively with the Novelty Seeking dimension (r=0.4, p=0.0005) of the TCI-R. The SSRT was positively correlated with the Novelty Seeking scale of the TCI.

Figure 5-7 A higher SSRT was positively correlated with Novelty Seeking of the TCI



r= 0.4, p=0.0005

Figure 5-8 The SSRT was negatively correlated with the self-control subtrait of the BIS



r= -0.3, p=0.005

5.3.7 Temporal Discounting Constant and Questionnaires

The Temporal Discounting Constant (TDk) correlated negatively with the second order subtrait of motor impulsivity (r=-0.2, p=0.01) of the BIS and with none of the TCI-R dimensions.

5.3.8 Gender and Questionnaires

When comparing the difference in subtraits of the BIS between genders, females scored higher (therefore less effective) on Non-planning (27.3 (SD=7.6) *vs.* 23.2

(SD=5.9), p=0.002), whereas males scored significantly higher on Self-control (17.6 (SD=3.7) *vs.* 15.0 (SD=3.9), p=0.03) and Cognitive Complexity (14.6 (SD=3.6) *vs.* 12.9 (SD=4.1), p=0.02). A comparison between sexes using the TCI-R showed no difference between males and females in the Novelty Seeking dimension (88.2 (SD=20.9) *vs.* 94.8 (SD=17.6), p=0.09). However, women scored higher in the Harm Avoidance dimension than men (99.5 (SD=14.20) *vs.* 91.8 (SD=12.9), p= 0.05).

5.4 Discussion

The SRRT of the Stop Signal Task seemed to differentiate sufficiently between the four groups tested. It was also the only behavioural measure to correlate significantly with BMI. Although there was a difference in impulsivity as expected between the adult groups they did not reach significance against each other. This may be explained by impulsivity plateauing with age, leading to less variability between adults. As people become older they are supposed to become less impulsive and indeed age was a predictor of the SSRT. The order of impulsivity with age and normative data estimates can be found below (See Figure 6-9).

Figure 5-9 Figure illustrating impulsivity scores

	Actual SSRT	Age	Normative SSRT
Obese Adolescents	218	14.3	236 (SD 74.8)
Bariatric patients	185	42.2	Unmeasured
Normal Adults	157	23	153-170
Normal Adolescents	153	13.8	166.4
Lifestyle adults	152	39	153

Normal weight adults were found to be more impulsive than normal weight adolescents on performing the Stop Signal Task. Although non-significant this is an unexpected finding. However, this may be explained firstly by the candidates' demographics. The adolescents were from a privately funded school and tested pre-exam time when self-control reserve would be expected to be high. The normal weight adolescent group had a mean age of 13.8 years-old, when impulsivity is not thought to be at its peak. The second reason for this discrepancy is that the adult control group is significantly younger than the remainder of the adult groups (mean age of 23 years-old). Most of the adult group were in their first year of university and are young adults in whom one may expect to be at an incomplete transition from the incentive processing system to the cognitive control system.

The Stop Signal Task did not differentiate between the sexes for impulsivity measures. However, females were found to be more impulsive than males on the monetary temporal discounting task. The difference in neurobiology (Manuk et al. 1999), cognitive styles and social expectations (Calvete and Cardenoso, 2005) has led to the suggestion that men are more impulsive than women. Therefore, these findings are contradictory to findings in the general population. However, obese women have been reported to be more impulsive than their normal weight counterparts using a monetary temporal discounting task (Weller, Cook, Avsar, & Cox, 2008) and patient with binge eating disorder a condition associated with impulsivity are predominantly female (Nasser, Gluck, & Geliebter, 2004). However, these results are mixed across samples (Gaub & Carlson, 1997; Rinne, Westenberg, den Boer, & van den Brink, 2000).

Adults who chose to attend the lifestyle intervention were found to be the least impulsive of all the groups. This is an unexpected result as these individuals had a significantly larger BMI than the control adult group. These findings suggest that the mind set of those entering lifestyle management is more stringent, with greater top-down control as shown by better performance on both the SST and Temporal discounting task.

The Novelty Seeking dimension from the TCI consistently correlated with both BMI and the SSRT. Novelty Seeking has been shown by Cloninger to be a poor prognostic variable in adults who attended a lifestyle intervention (Sullivan, Cloninger, Przybeck, & Klein, 2007). Self-control in the Barratt's Impulsivity Scale was negatively associated with both BMI and the SSRT. Therefore, individuals with poor self-control were more likely to be heavier and impulsive with regard to inhibitory control.

Novelty seeking is also an important construct in the study of substance abuse and studies of novelty seeking have generally found indirect effect through self-control (Patock-Peckham, Cheong, Balhorn, & Nagoshi, 2001; Wills, Sandy, & Shinar, 1999) and in this clinical group self-control has proven to moderate the level of substance use (Wills et al., 2002).

From these results it seems feasible to use the chosen tasks as predictors of impulsivity in obesity. The Stop Signal Task appears to be the most robust measure and correlates well with the impulsivity components of the personality questionnaires. This is supported by a 37.4% of variance in BMI (r-square) being explained by the Stop Signal Reaction Time.

SUMMARY

- SSRT identified the following groups in order of increasing impulsivity: adult lifestyle, normal adolescent, normal adults, bariatric patients and obese adolescents
- SSRT was a predictor of BMI
- SSRT correlated positively with BMI
- SSRT correlated with poor self-control on the BIS
- SSRT correlated with Novelty Seeking on the TCI
- Females were found to be more impulsive than males using the temporal discounting task

Chapter 6 Impulsivity as a predictor of weight loss in obese adolescents.

6.1 Introduction

Childhood and adolescent obesity is on the rise globally (Lobstein, Baur, & Uauy, 2004). Childhood obesity tracks into adulthood (Whitaker, Wright, Pepe, Seidel, & Dietz, 1997), making weight related behaviours likely to be sustained throughout one's life and significantly contributing to obesity related comorbidities in adult life.

Obese children have been shown to be more impulsive than their non-obese counterparts using behavioural tasks and personality questionnaires (Batterink, Yokum, & Stice, 2010; Sullivan, Cloninger, Przybeck, & Klein, 2007). Obese adolescents have shown to discount both food and monetary rewards more than normal weight individuals, choosing a smaller more immediate reward over a larger delayed reward, otherwise known as poor action restraint (Weller, Cook, Avsar, & Cox, 2008). The resulting suboptimal decision-making processes mean that making healthier diet and exercise choices may be diminished in obesity. Both temporal discounting and poor inhibitory control have been associated with a greater Body Mass Index (BMI), poor treatment outcomes for weight control and long-term weight gain (Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010; Nederkoorn, Jansen, Mulkens, & Jansen, 2007; Pauli-Pott, Albayrak, Hebebrand, & Pott, 2010).

Adolescents are a prime age group in which to study impulsivity as their neurocircuitry is at an intermediate stage of development, balancing self-regulation and impulsive tendencies (Eigsti et al., 2006). In a recent review of obesity interventions for children and adolescents, residential weight-loss programmes for adolescents with a minimal stay of 10 days has seen average reductions of 22.9% in percentage overweight (Kelly & Kirschenbaum, 2011). It has been suggested that the non-obesogenic environment, coupled with the multidimensional components such as controlled diet, physical activity, nutrition activity, nutritional education and behaviour change techniques are key drivers of their success.

Currently available evidence relating impulsivity to obesity is predominantly cross-sectional with an isolated measurement of impulsivity (Thamotharan, Lange, Zale, Huffhines, & Fields, 2013). The longitudinal change in behavioural measurements of impulsivity with weight loss is unreported. A longitudinal study will allow any relationship between baseline impulsivity measures and change in BMI to emerge. It will also allow for any changes in impulsivity with reduction in BMI to emerge. These test changes will provide an indirect measure of brain pathways that may be altered with weight reduction.

Endophenotyping

The two facets of impulsivity (inhibitory control and temporal discounting) were studied in this study using computerised cognitive tasks as an intermediate marker of brain dysfunction (endophenotyping). Neuroscience research has found three interacting brain networks that mediate reactive (or reflexive) and proactive (reflective) behavioural control (Corbetta & Shulman, 2002; Fox, Corbetta, Snyder, Vincent, & Raichle, 2006; Seeley et al., 2007; Sridharan, Levitin, & Menon, 2008).

Inhibitory control was considered a surrogate measure of the Salience Network (SN). As the adolescent group lose weight, the SN mediates this change through an improved top-down control; one would expect an improvement in inhibitory control as signified by a lower SSRT at the end of the residential camp. The Default Mode Network was operationalized by the Temporal Discounting Task and as it is thought to represent neural mechanisms to help achieve long-term goals. If there were subtle change in temporal discounting with weight reduction, there would be an accompanying reduction in participant's temporal discounting constant (TDk).

6.2 Methods

6.2.1 Participants

Fifty-three adolescents were recruited from camps between July and September 2011 and 2012. The group included 20 boys and 32 girls aged between 10 and 17 years-old (mean age 14.28 ±1.7). Participants BMI ranged from 22.7 to 76.3 (Average BMI 33.75 ± 7.9) (see Table 1). Adolescents stayed in the camp between 2 to 8 weeks (mean weeks 7.36 ±1.15). The local health authority funded 45 of the 53 participants; these individuals remained in camp for the entire 8 week period. The remainder was privately funded. Consent was gained from parents in all cases. Children were included in the study if obese or overweight when adjusted for age and sex. All adolescents were in regular education. Participants were excluded if they had a formal diagnosis of ADHD, an eating disorder, taking antipsychotic medication or had a physical disability. The medical ethical committee of Leeds Metropolitan University approved the study.

6.2.2 Multi-dimensional Weight Loss Intervention

The 8 week intervention was a lifestyle multi-dimensional intervention. The curriculum was based on 8 core skills and strategies which focus on behaviour change. The key components of the intervention were: Stimulus control, monitoring, behaviour shaping, alternative responses, goal setting, planning, problem solving and time management. The participants were given a structured daily routine, which involved physical activity in the form of a team sport.

6.2.3 Control Group

Fifty non-obese adolescents with a BMI range of 16.5 to 24.5 (mean BMI 20.6 ±2.13) and with a mean age of 13.82 years-old (± 1.7) were recruited from a secondary school during a two week period. Consent was gained from parents in all cases. Children were entered into the group if they had normal BMI when adjusted for age and sex. The same inclusion and exclusion criteria were applied as to the intervention arm.

6.2.4 Measures

BMI

A single staff member using the same calibrated scale and the wall-mounted stadiometer carried out all measurements to calculate the BMI. All children referred to the camp had a BMI above the 85th percentile and were all obese or overweight (Must & Anderson, 2006).

6.2.4.1 Primary Measures

Behavioural measures of impulsivity included the Stop Signal Task and the monetary Temporal Discounting Task.

Junior Temperament and Character Inventory

Behavioural measures were supplemented by the Junior Temperament and Character Inventory (JTCI). To assess personality the JTCI was used. The JTCI is based on Cloninger's biosocial model of personality. The reliability and validity of the Junior TCI has been reported in a number of different cultures (Chotai, Jonasson, Hagglof, & Adolfsson, 2002; Gothelf, Aharonovsky, Horesh, Carty, & Apter, 2004; Lyoo et al., 2004). The JTCI was a singular measurement at the beginning of camp as it is a self-report measure of personality trait and therefore unlikely to reflect any change of the individual personality state.

The questionnaire divides personality into temperament and character dimensions[i]. Temperament is a moderately heritable, temporally stable personality trait with a biological basis. Character is influenced by ones environment and social learning and less influenced by genetic factors. Both character and temperament dimensions are believed to predict the diagnosis of specific personality disorders (Cloninger, 1987). The parent report comprises 84 items and assesses 4 temperament dimensions (Novelty Seeking, Harm Avoidance, Reward Dependence and Persistence) and 3 character dimensions (self directedness, cooperativeness and self transcendence) about the child. The children's component of the questionnaire comprises of 108 items capturing the same dimensions. The Novelty Seeking dimension for the JTCI is associated with impulsive decision making and has been shown to be positively related to impulsive Sensation Seeking from Zuckerman's model of impulsivity (Schmeck, Goth, Poustka, & Cloninger, 2001).

In addition to the primary measures of impulsivity, three secondary measures were also chosen. The relationship between wellbeing and obesity has been well documented and may play an intermediary role between weight and impulsive behaviours (Tsiros et al., 2009). Body dissatisfaction and physical activity are two key factors in weight reduction in the adolescent population, so, their relationship with obesity was studied.

6.2.4.2 Secondary Measures

Body size dissatisfaction. Body dissatisfaction is significantly higher in overweight and obese youth than normal weight youth (Goldfield et al., 2010). Obese females are more likely to be dissatisfied with their body morphology in the community setting than normal weight adolescents (Duncan, Al-Nakeeb, Nevill, & Jones, 2006). The Stunkard Scale is a series of progressively heavier body types labeled 1 to 9, with 9 being the heaviest. The score is derived on how far their ideological self is from their perceived self.

Physical activity. The individuals exercise ability was determined by their lap time for a two-mile challenge run each week in camp. Goal setting was used to set a personalised best.

6.2.5 Statistics

The Statistical Package for the Social Sciences (SPSS), Version 19 (IBM), was used for statistical analysis. The pre-post change in BMI due to the intervention, the difference in impulsivity measures between the control and intervention group, the subjective wellbeing and secondary measures were assessed using a paired t-test. SSRT, temporal discounting constant (TDk) and BMI were compared using a multi-variate analysis for inter-subject variation (repeated measure General Linear Model (GLM). Sex was taken to be a between-subject factor. All other parameters were entered as covariates (see Figure 6-2). Novelty Seeking was the only dimension from the JTCI added to the GLM as it is thought to be the most robust measure of impulsivity of all the variables. A Linear regression using the changes in BMI, subjective wellbeing and length of stay was undertaken. In addition, a stepwise linear regression was used for determining predictors of change in BMI, change in SSRT and the number of weeks in camp.

Figure 6-1 Participant demographics of the camp setting

Participants	53
Sex	M=20 F=32
Age	14.28 ± 1.7
Weeks	7.36 ± 1.15 (2-8 weeks)
BMI	33.75 ± 7.89 (22.7-76.3)
PCT Funding	45

Figure 6-2 A list of all covariates added to repeated measures GLM

Dependent Variable	Change in BMI	Change in SSRT	Change in Temporal Discounting
Between subject factor	Sex	Sex	Sex
Co-variates	Weeks in camp Age Child NS Initial SSRT Change in SSRT Initial Temporal Discounting Change in Temporal Discounting	Weeks in camp Age Change in BMI	Weeks Age

6.3 Results

6.3.1 SSRT: obese compared to normal weight

The non-obese group were found to have better inhibitory control as measured by the SSRT with a mean value of 156.93 ± 43.12ms, compared with the obese group with a mean value of 218.42 ± 80.48ms (p=0.0001). Multiple parameters of the Stop Signal Task were found to be significantly different between both the obese and non-obese group. The SST direction errors were significantly higher in the obese adolescents (5.48 ± 4.88) than normal weight individuals (2.88 ± 0.41, p=0.0001) at baseline. Similarly, the proportion of successful stops were significantly higher in the normal weight adolescents (0.49 ± 0.1), than the obese group (0.53 ± 0.09, p=0.021). There was no difference between the reaction times on the Go-trials between both obese (393.78 ± 100.98 ms) and non-obese individuals (374 ± 108ms, p=0.379). The stop signal delay time when the subjects were able to stop 50% of the time was less for the obese group (172.15 ± 104.8ms) than the non-obese group (218.05 ± 95.72ms, p=0.026).

6.3.2 Temporal Discounting: obese compared to normal weight

Those who were obese (k=0.56 ± 0.36) were found to discount the future more than normal weight individuals (k=0.40 ± 0.29, p=0.018).

6.3.3 JTCI and correlation with behavioural measures

The JTCI questionnaire results were pooled for both the obese and non-obese groups. The SSRT did not correlate with any parameters of the JTCI. The monetary temporal discounting constant correlated with the Novelty Seeking temperament of the JTCI ($r=0.23$, $p=0.029$). There was no significant difference in any of the personality dimensions between both groups.

6.3.4 Predictors of Obesity

A logistic regression (n=103) found that SSRT (B=0.021,W(1)= 14.47, p=0.001), the temporal discounting constant (B=1.89, W(1)=4.76, p=0.029) and age (B=3.32, W(1)= 4.04, p=0.04) could significantly predict those who were more likely to be obese.

BMI reduced significantly overall before and after camp by 2.83 ± 0.29 kg/m^2 from 33.76 kg/m^2 to 30.93 kg/m^2 with a mean stay of 7.36 (range 2-8 weeks) weeks in camp. There was a greater reduction in BMI in boys (3.17 ± 0.89 kg/m2) than girls (2.62 ± 0.89 kg/m2) (t=-2.817, p=0.03). A repeated measures GLM using the pre and post BMI as the dependent variable found the number of weeks in camp (Wilks' Lambda= 0.73, $F(1,50)=12.35$, p=0.001), initial SSRT score (Wilks' Lambda=0.82, $F(1,50)=5.40$, p=0.026) and the change in SSRT (Wilks' Lambda= 0.90, $F(1,50)=4.85$, p=0.034) to significantly predict the reduction in BMI. A multiple regression model with the change in BMI as a dependent variable produced a good fit (R2= 0.549, F (1,53)=4.47, p=0.0004). A longer stay in camp was associated with a greater reduction in BMI (B= 0.396, β=0.432, p=0.007). The initial SSRT also showed a significant effect size (B=0.003, β=0.297, p=0.04). The age of the participants (B= 0.94, β= 0.171, p=0.191), and initial temporal discounting constant (B= 0.299, β=0.820, p=0.417) were not associated with a reduction in BMI.

A stepwise regression using the change in BMI as the dependent variable found the weeks in camp (R^2=0.649, F(1,53)= 10.36, p=0.0001) as the first predictor, Initial SSRT (R^2=0.351, F(1,53)= 7.78, p=0.012) as the second predictor and the change in SSRT (R^2=0.32, F(1,53)= 7.6, p=0.023) as the final predictor to all be significant.

6.3.5 Change in SSRT pre and post camp

The SSRT decreased from 225.38 ± 94.22 ms pre-camp to 173.76 ± 107.05 ms post-camp, with its mean fall of 51.62 ± 82.71 ms (N=47, p=0.0001). Repeated measures GLM showed that both weeks in camp (Wilks' Lambda= 0.831, F(1,50)=9.83, p=0.003) and the age of the adolescents (Wilks' Lambda= 0.87, F(1,50)=5.98, p=0.02) were significantly associated with a reduction in the SSRT. A longer stay in camp was associated with a greater reduction in SSRT (B=25.45, β=2.02, p=0.05). Increasing age played a significant moderating role in the reduction of inhibitory control (B=-0.3, β=-0.034, p=0.05). There was no difference in the initial inhibitory control as measured by the SSRT between sexes (t(1)=1.16, p=0.29). There was also no difference in the reduction in SSRT between girls and boys during camp (t(1)=1.04, p=0.23).

6.3.6 Change in Temporal Discounting pre and post camp

The overall temporal discounting constant (TDk) post-camp fell significantly from 0.55 ± 0.37 to 0.42± 0 .40 which is a mean fall of 0.13 ± 0.38 (N=46, p=0.018). In a real life scenario, the application of the new discount constant would mean that, if £50 were to have value of £23.81 in 2 weeks at the beginning of camp. At the end of camp the value of the £50 had risen to £27.17. Showing there is less subjective depreciation for the value of money. Repeated measures GLM showed no relations between age (Wilks' Lambda= 0.997, F(1,50)=0.007, p=0.64), the number of weeks in camp (Wilks' Lambda=0.999, F(1,50)=0.004, p=0.95), change in BMI (Wilks' Lambda= 0.994, F(1,50)=0.37, p=0.55) and initial wellbeing (Wilk's Lambda= 0.978, F(1,50)=0.93, p=0.34) on the reduction in temporal discounting. There was no difference in the baseline temporal discounting score between girls and boys (t(1)=0.15, p=0.70) or change in temporal discounting during camp (t(1)= 1.14, p=0.56).

6.3.7 Correlation with JTCI

The parental response to the questionnaire was poor (23/53 responses). The adolescent's score on the JTCI were correlated with the pre-camp temporal discounting constant (TDk) and the pre-camp SSRT. From the temperament dimension, only child Novelty Seeking which encompasses impulsiveness as a sub-group, correlated significantly with the TDk (r= 0.338, p=0.03). A correlation between the parental and child score showed that parental Novelty Seeking correlated with child Harm Avoidance (r=-0.49, p=0.03) and with the child self reported Novelty Seeking score (r=0.44, p=0.008). The parental and child Harm

Avoidance scores correlated significantly (r=0.69, p=0.001). The only other significant correlation was between the parental Cooperativeness scores and the child Self Directedness scores (r=0.43, p=0.05).

6.3.8 Secondary outcomes

There were improvements in multiple secondary outcomes during camp. The individual times for the two mile challenge improved significantly from 35.23± 6.29 mins to 28.96± 8.52 mins (n=45, p=0.0001) during camp. Self perception of body habitus improved significantly before and after camp from a discrepancy score 33.54 ±17.60 between the ideal self and perceived self to 22.85± 15.94 (n=45, p=0.001). There was a significant improvement in the diastolic blood pressure by 7.04 ± 15.91 mmHG (n=48, p=0.001).

A stepwise multiple linear regression in which the change in inhibitory control was used as the dependent variable found a younger age (R2=0.42, F(1,53)=2.2, p=0.04) and an improvement in the two mile challenge time (R2=0.22, F (1,53)=2.1, p=0.04) to be significant predictors of a reduction in impulsivity. An improvement in the two-mile challenge time alone was a predictor of a reduction in temporal discounting (R2=0.23, F=(1,53)=7.7, p=0.009).

6.3.9 Length of Stay

As the length of stay in camp was shown to be related to a decrease in SSRT, temporal discounting, BMI and fitness. A stepwise regression model in which the control variable was the length of stay at camp was entered in the first step and all other hypothesized variables (initial SSRT, change in SSRT, initial K, change in K and initial BMI) were entered subsequently, showed that the number of weeks in camp were predicted by the initial SSRT ($R2=0.09$, $F(1,53)= 4.18$, $p=0.05$) and change in SSRT ($R2=0.22$, $F(1,53)$, $p=0.09$). Both the Temporal Discounting constant ($R2= 0.23$, $F(1,53)=0.21$, $p=0.65$) and the change in Temporal Discounting constant ($R2=0.23$, $F(1,53)=0.004$, $p=0.949$) were unrelated to the number of weeks in camp.

6.4 Discussion

This study shows a reduction in impulsivity and an improvement in subjective wellbeing as part of a multi-dimensional weight loss intervention. A residential camp setting provides a controlled environment in which to support weight loss away from external food cues and psycho-social influences which may act as cofounders.

The change in interaction between the interconnected neuronal networks may explain the mechanism by which the weight loss is associated with a reduction in impulsivity. The Stop Signal Task acts as a visual and auditory cue to test the external sensory component of the salience network (Bonnelle et al., 2012). Better performance at the stop trial requires a transition from relatively automatic to highly controlled behaviour. An improvement in the stop signal reaction time during camp is likely to represent better top-down control by the executive control network over the reactionary salience network. The improvement in the Temporal Discounting Task reflects greater cognitive control through strengthening of the default mode network by a more goal directed approach, which favours waiting for a larger delayed reward. It is feasible to compare monetary reward as a surrogate marker for food. The activation of the reward circuitory in response to receipt of food and monetary reward, in groups at high risk of obesity has shown a common reward pathway for both commodities (Stice, Yokum, Burger, Epstein, & Small, 2011). The IOWA Gabbling Task, for example, tests decision-making deficiency in eating disorders using monetary choices (Danner, Ouwehand, van Haastert, Hornsveld, & de Ridder, 2012). Connectivity in the default mode network is reduced in obese individuals (Garcia-Garcia et al., 2012). During camp, activity in the default mode network is strengthened along side components such as social cognition and self-referential processing which are essential components to future self-projection and goal-orientated behaviours (Spreng, Mar, & Kim, 2009). A goal-oriented approach is further supported by an improvement in body perception scores during camp, shown by a smaller difference between their ideal body habitus and their current body image (Davidson, Kanoski, Schier, Clegg, & Benoit, 2007).

There are treatment implications with regard to the potential treatment options that address impulsivity for weight reduction. There is now emerging evidence that higher order learning and memory processes based in impulsivity, such as practicing self-control and mindfulness during meals may play an important role in eating behaviour (Ogden, 2007).

There is a specific improvement in subjective wellbeing for various aspects of participant's lives including school, family and home individuals despite individuals not having experienced these environments physically since their stay in camp. The change in wellbeing is secondary to a projected future vision of oneself in a given domain the individual would like to achieve. In support of this, activity in the default mode network, which is believed to strengthen during camp, is thought to be associated with eudemonic wellbeing such as meaning and purpose (Berridge & Kringelbach, 2011).

Increased physical fitness represented by the 2 mile challenge was found to be a significant contributor to the fall in inhibitory control, improvement in the temporal discount rate and subjective wellbeing during camp. It was also the associated weight reduction. However, the interplay between these three variables is unclear. It may well be that increased inhibitory control might increase physical performance by elevated motivation or perseverance. The causal association between physical fitness and impulsivity is difficult to delineate but it has been hypothesized that the impulsive eating drive may be counteracted by physical activity due to its enhancement of neurocognitive resources for executive functions and goal oriented behaviour. In the child and adolescent population, physical activity has been shown to have a positive effect on cognition (Hillman, Erickson, & Kramer, 2008). By enhancing the resources that facilitate 'top-down' inhibitory control, increased physical activity may help compensate and suppress the hedonic drive to over-eat.

Time spent in camp was a major contributor to weight reduction and may have been associated with a reduction in impulsivity. There was a variation in the number of weeks each individual spent in camp but none of the participants withdrew from intervention prematurely meaning attrition rates do not contribute to any biases related to the reduction in SSRT. As 45 of the 53 adolescents stayed in camp for 8 weeks and 8 self-funded participants stayed for a mean period of 3.0 ± 1.0 weeks. This suggests that the small subgroup may be responsible for the large effect of the length of stay. However, a comparison of the baseline SSRT, temporal discounting constant and BMIs did not identify any overt causal outliers for this effect. The mean initial SSRT scores for the group with the longer stay were 221.02 ± 14.23ms (100.53-554.0ms) versus 239.67 ± 35.47ms (173-405ms) for the short stay group and were comparable. The temporal discounting constant in the long stay group was 0.582 (7.44x 10^{-4} -1) and was 0.735 (0.344-1) for the short stay group (p=0.14). Similarly, the BMI was comparable between both groups (long stay group; 34.24 ± 3.6, versus; 33.36 ± 9.3, p=0.23).

Finally, younger adolescents were found to be more amenable to a reduction in impulse control than older adolescents. This is an important finding with practical implications, as younger adolescents are better candidates for behavioural change, which could be a reflection of the plasticity of their neuronal networks.

There are obvious limitations due to the quasi-experimental design of the study. A suitable control group would be obese adolescents not undergoing any form of intervention followed up over the same period of time to compare differences due to the intervention, reflection of practice or maturation of adolescents over the time period.

Functional imaging to support the existence of the neuronal networks involved in impulse control is necessary and may be an important variable to factor in when developing weight loss interventions. As the weight loss intervention is multi-modal it may be difficult to siphon out which of the components within the behavioural therapy contribute to impulse control. There is also a need for a better understanding of the changes in impulsivity with prolonged weight loss. Adolescents in camp are in effect restraint eaters similar to dieters. In the long-term restraint eating rarely lead to successful weight loss, therefore follow up at 1 year post intervention will better show the trends in impulsivity. Successful policy strategies are required for weight reduction in adolescents and to date it is unclear exactly what these are. In the short term we show that National Health Service funded residential camps not only help reduce weight but make happier children and modify behaviours measured objectively. The challenge is to maintain these changes in the long-term with community support.

Chapter 7 Temporal discounting as a predictor of community weight loss maintenance in adolescents

7.1 Introduction

The problems associated with childhood and adolescent obesity have been highlighted in the previous chapter. It is a consistent finding that the weight lost by obese patients as a result of the most widely available treatments for obesity such as pharmacotherapy (Rucker, Padwal, Li, Curioni, & Lau, 2007) and behavioural treatment (Shaw, O'Rourke, Del Mar, & Kenardy, 2005) is almost always regained over time. Typically half the weight lost is regained in the first year following treatment with weight regain continuing thereafter, so that 3-5 years post-treatment about 80% of patients have returned to or exceed their pre-treatment weight (Wadden & Frey, 1997; Wadden, Sternberg, Letizia, Stunkard, & Foster, 1989). In a study with children aged 7 to 17,admitted to a 10 month treatment program for obesity, Braet (2006) found that after 2 years, overweight was still prevalent in most children and 73% of the children had regained weight after discharge (Braet, 2006).

Therefore, prediction and maintenance of weight loss remains an important aspect of research in obese adolescents. Participants who entered the residential weight loss camp were followed-up in a tailored community intervention designed to maintain weight loss. The full community intervention was designed to moderate impulsive behaviour and is described fully in Chapter 7. This chapter shall focus on the use of behavioural impulsivity measures as a predictor of weight loss over the maintenance phase.

7.2 Method

Twenty-seven of the 50 adolescent participants who entered the summer residential camp in 2011 were recruited with parental consent, into a 12-week community intervention. Participants were randomized into receiving either weekly commitment or information text messages. Text messages were augmented with fortnightly telephone calls. The contents of the messages were taken from the MORELife syllabus which provides a framework for education and behavior change by providing physical resources for children, parents and staff delivering the programme. The syllabus consists of a range of food and physical activity behaviours that are related to weight and health of young people: portion control, structured eating, reduced fat and sugar, reduced sweetened beverages, one hour of physical activity involving team sports and exercise routines, reducing sedentary behaviours.

7.2.1 Measurements

Anthropometric measures

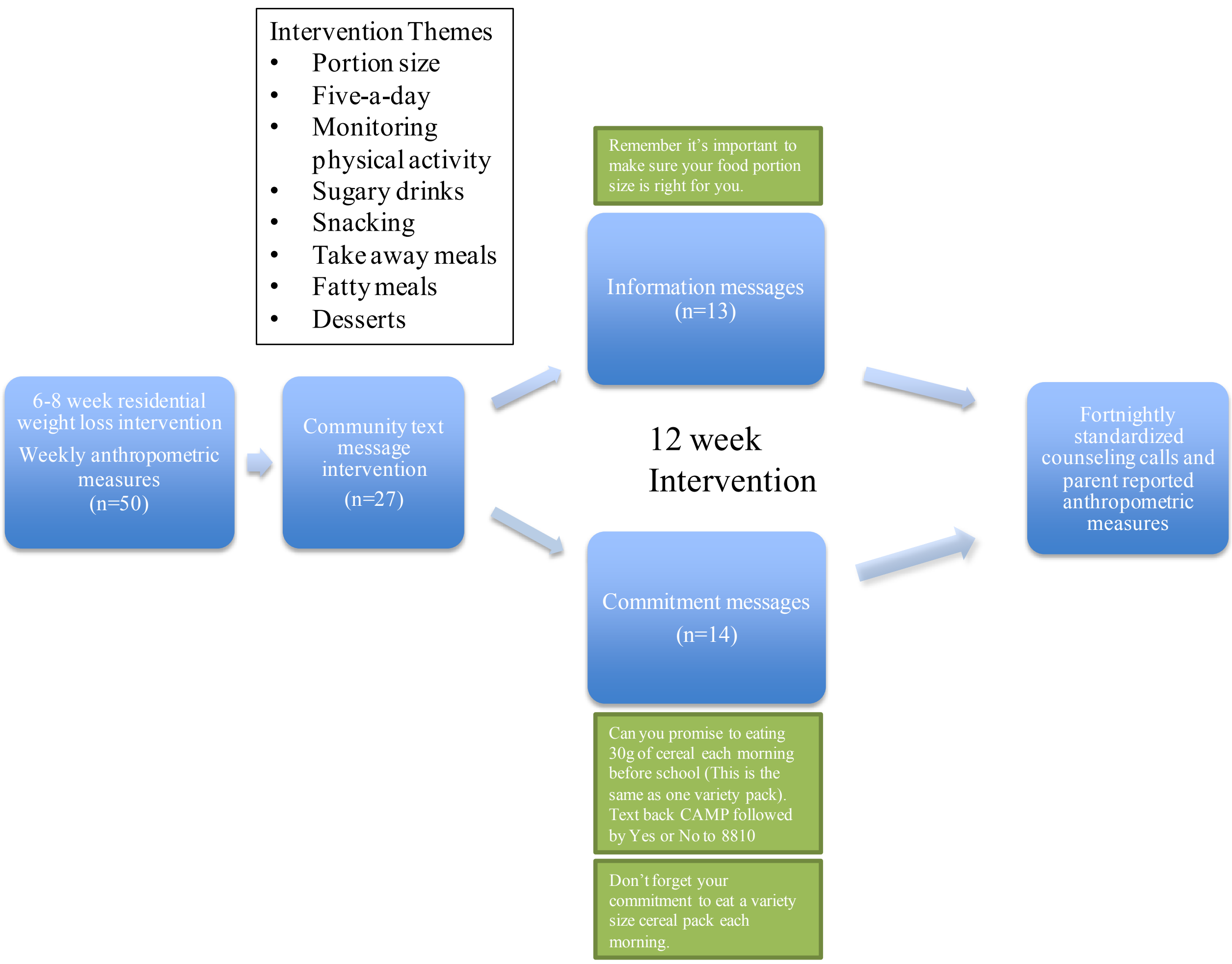
BMI was measured objectively by a single researcher pre and post residential camp and at 12 weeks after the maintenance intervention.

Behavioural measures

All behavioural measures (Temporal Discounting and Stop Signal Task) were conducted pre and post residential camp. Pre residential camp impulsivity measures and a change in impulsivity during the residential camp were regressed against the percentage change in BMI during the maintenance phase of the intervention.

The figure below (Figure 8-1) illustrates the community intervention. Impulsivity was measured before and after the residential camp setting. Objective BMI measurements were taken regularly during the camp after the 12-week community intervention.

Figure 7-1 Diagram illustrating the community intervention



7.3 Results

7.3.1 Baseline characteristics

7.3.1.1 BMI

At the end of the residential camp, 5 males and 8 females of age 13.69 (SE=0.38) with a mean BMI of 32.19 (SE=2.16) were assigned to the information arm. The age-matched (13.78 (SE=0.40)) commitment arm had 4 males and 10 females with a comparable mean BMI of 31.29 (SE=1.15). The two groups had equal start in the post-camp intervention as their weight loss during the residential camp (before our intervention began) in both arms were equivalent with a fall in BMI of -2.63 (SE=0.32) in the informational arm and -2.32 (SE=0.27) for those assigned to the commitment arm; and the difference between the two groups was not statistically significant in this respect (t = 0.75, p = 0.462).

7.3.1.2 Impulsivity

Participants in the commitment arm (n=12) had an SSRT of 244.24 ms (SE 27.60) compared to 267.17 ms (SE=83.63) for those in the information arm (n=6) (t=-0.50, p=0.625). Impulsivity as measured by the Temporal Discounting Task found the participants of the commitment arm (n=13) to have temporal discounting constant of 0.30 (SE=0.09) compared to 0.41 (SE=0.14) in the information arm (n=7) (t=-0.67, p=0.51). There was no statistical significance between groups in either measure of impulsivity.

7.3.2 Pre Post Intervention change

7.3.2.1 BMI

BMI decreased in the commitment condition by 0.12 (SD=1.93; Z = -0.41, *p* = .341), however this was non-significant. While in the information condition, BMI significantly increased by 1.06 (SD=2.34; *Z* = -1.73, *p* = .042) after the maintenance intervention.

7.3.2.2 Impulsivity

A one-way ANOVA showed that there was no difference in impulsivity between both groups. The SSRT in the commitment arm fell by 12.09 ms (SD=35.13) compared to 21ms (SD=23.85) in the informational message arm (F(1,15)= 0.034, p=0.857). Similarly, the Temporal Discounting Constant also showed a non-significant reduction, with the commitment arm having a fall of 0.017 (SD=0.13) and the information arm a fall of 0.21 (SD=0.14) (F (1,12(= 0.716, p=0.41).

7.3.2.3 Predictor of weight change

In order to illustrate the overall effect of the impulsivity measures on the change in BMI, all data was pooled. A stepwise linear regression, with the percentage BMI change during the maintenance as a dependent variable, was performed. With age, gender, intervention arm, initial SSRT, initial temporal discounting constant, change in SSRT and change in Temporal Discounting Constant entered as the independent variable was calculated. The overall model was significant R^2= 0.375, F=(1,12)=7.21, p=0.02. The initial Temporal Discounting Constant (B=11.55, t=2.68, p=0.02) was found to be the single most significant predictor of a reduction in BMI during the maintenance phase. The only other variable near significance was the change in SSRT (B=0.43, t=2.18, p=0.05). All other variables showed no relationship to the percentage change in BMI: Age (B=0.19, t=0.79, p=0.45), change in temporal discounting constant (B=-0.37, t=-1.48, p=0.17), Initial SSRT (B=0.22, t=0.91, p=0.38) and Gender (B=0.03, t=0.12, p=0.91) and text message group (B=0.36, t=0.16, p=0.13).

7.4 Conclusion

Previously an improvement in stopping impulsivity as measured by inhibitory control was found to be a predictor of weight reduction in the same group of adolescents over a period of two to eight weeks. The current study supports the role of temporal discounting as a predictor of weight loss during the three month community maintenance. The study uses monetary reward instead of hypothetical or real life health scenarios to test temporal discounting. The field of behavioural economics has long used monetary options as a substitute for health related choices (Story, Vlaev, Seymour, Darzi & Dolan, 2014). This is because engaging in healthy behaviours is considered in economic terms to making a long-term investment (Grossman, 2013). Therefore it is considered that monetary discount rates ought to be able to explain why people invest in such behaviours. The concept of money itself develops as young as three years of age, in a consistent and cumulative manner. This is often before a child is ever able to contemplate health related outcomes (Berti & Bombi, 1981; Strauss & Schuessler, 1951). In support of our methods, a handful of studies have supported a good correlation between *in vivo* health choices with monetary discount rates (Baker, Johnson, & Bickel, 2003; Chapman et al., 2001; Chapman & Coups, 2006; Khwaja, Silverman, & Sloan, 2007).

Behavioural measures of impulsivity are described as surrogate markers of neuronal pathways in the field of endophenotyping. Measurements and changes in stopping impulsivity are thought to describe activity in the salience network (SN) of the brain, a mediator of top down regulation. It is thought that more obese individuals rely on reactive behavioural control, subserved by the salience network. Whereas activities in a second network the default mode network (DMN) was measured using the monetary temporal discounting task. The DMN is responsible for controlling our behaviours leading to the attainment of long-term goals. The final network is the executive control network, which is involved in voluntary top-down control. The executive control network is operant when extra cognitive control is required to process sensory information for immediate actions. If the salience network were to represent the go-trials of the stop signal task, the executive network would be represented by the no-go trials, as it works in antagonism with the salience pathway.

Current finding suggest those who already have greater activity in the DMN as shown by performance in the temporal discounting task are likely to maintain their weight loss despite any transient or long standing improvements in the salience network.

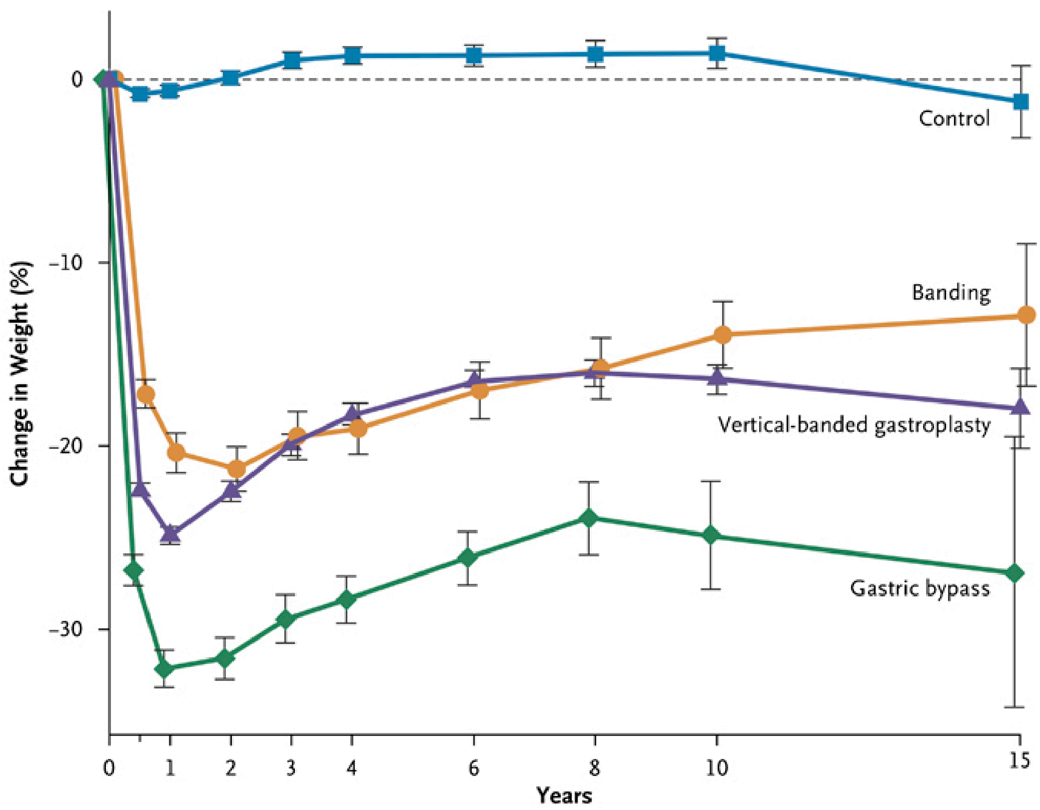
Commitment text messages were used in the intervention arm of the maintenance phase, as they are thought to target the ‘automatic’ decision making process which is described as being uncontrolled, effortless, associative, fast and unconscious. The proposed psychological mechanisms by which commitments may yield successful behaviour change include automatic impulses to maintain positive self-concept and image, which drives individuals to be consistent with their public promises (Dolan et al., 2012). For the first time an objective maintenance of weight loss was observed in the adolescent population by the use of commitment techniques. However we can only speculate that commitments specifically target the DMN as they are responsible for controlling our behaviour leading to the attainment of long term goals. Therefore, this study supports evidence for the role of impulsivity in weight loss maintenance through both a prognostic (endophenotyping) and explanatory (commitment intervention) exploration of the multifaceted concept of impulsivity.

Chapter 8 Impulsivity as a predictor of weight loss in bariatric patients

8.1 Introduction

The bariatric patient group is an important one when considering the role of impulsivity in weight loss. Surgery is considered the treatment of choice in morbid obesity and weight loss strategies refractory to lifestyle intervention (Brolin, 2002). Bariatric surgery works in one of three ways. The first is by restriction of the stomach, which limits the amount of food intake such as a vertical gastric band or a sleeve gastrectomy. The second is limiting the absorption of food in the intestinal tract by bypassing a portion of the small intestine to varying degrees and; finally, a combination of the two, such as in a gastric by pass operation. Since most procedures that use malabsorption also use restriction the main mechanism by which weight loss after bariatric surgery occurs is due to a reduced intake of food. As the time period since the advent of bariatric surgery elapses and efficacy of procedures are evaluated, despite the favourable overall weight loss after bariatric surgery, it is clear that there is variability in the outcome and the body weight of many subjects do no fully normalize after surgery (Christou, Look, & Maclean, 2006) (see Figure 9-1). Post-operative weight loss is likely to be dependent on more than just the technical adequacy of the procedure and both demographic and personality factors have been implicated. Age, sex and pre-operative BMI have been found to be important modulators of outcome (Branson et al., 2005). A review of the psychological predictors of weight loss after bariatric surgery have identified that those who are younger, female, high self-esteem and of good mental health are likely to have greater success (van Hout, Verschure, & van Heck, 2005). Furthermore, in the UK, a leading national surgical report has highlighted the need to take psychological factors further into considerations in order to optimize weight management and wellbeing in bariatric surgical patients (NCEPOD, 2012). Results from the adolescent group suggest that the Stop Signal Reaction Time should be a predictor of weight reduction in the bariatric patient group (Kulendran et al., 2013). The study will be divided into two sections. Study 1 will be a prospective pilot study using the Barratt's Impulsivity Scale to determine whether personality traits predict short-term weight loss. In addition Study 2 also investigates the role of behavioural measures and commonly used dietary questionnaires in predicting weight reduction after two common bariatric procedures.

Figure 8-1 - Normalisation of BMI after bariatric surgery. Long-term follow-up (Swedish Obesity Study, Sjostrom et al., 2007)



8.2 Study 1

8.2.1 Method

The BIS was given to 50 bariatric patients referred to the Imperial Weight Management Centre on their first visit and collected on the same occasion. All patients were eligible for bariatric surgery as determined by the Planned Procedures with threshold criteria attended a 30 minute talk informing them of the surgical procedures available to them. The patients' medical history and Body Mass Index

(BMI) were recorded prior to surgery. All medical information was confirmed using patients' hospital notes. The patients were also examined in relation to other predictor variables of failure to weight loss as listed below.

Number of weight loss strategies.

The number of weight loss strategies (lifestyle interventions, commercial diets and pharmacotherapy) prior to seeking surgical intervention was determined, as a great number of previous weight loss attempts is associated with higher rates of attrition from weight loss programmes (Wadden TA, 1992) and maybe associated with poor post-operative weight reduction.

Psychiatric illness

This patient group are prone to psychological disturbances (Kinzl et al., 2006; Mamplekou, Komesidou, Bissias, Papakonstantinou, & Melissas, 2005; Schowalter et al., 2008; van Hout, Boekestein, Fortuin, Pelle, & van Heck, 2006). A history of, or current diagnosis of depression and anxiety, were specifically asked for.

Medical History

A number of obesity related patient co-morbidites were recorded, including: hypertension, diabetes, obstructive sleep apnoea and polycystic ovarian syndrome.

A list of their medications and their smoking, drug and alcohol history was also elicited.

Surgery

Of the 50 patients approached, seven were excluded as they had poor English, making it difficult for them to complete the questionnaire. Of the 43 patients enrolled in the study 37 were included in the analysis as they underwent one of three standard bariatric procedures (gastric band, gastric by-pass, sleeve gastrectomy). The remainder opted for lifestyle intervention in the community or pharmacotherapy. BMI's were objectively recorded at one-year follow-up.

Statistical analysis

A Spearman's correlation across all BIS subtraits against BMI and clinical parameters was undertaken. The clinical parameters chosen for correlation were: the number of weight loss strategies, comorbidities, medications taken and psychiatric diagnosis present through the lifespan. A repeated measures GLM, with the change in BMI pre and post intervention as the dependent variable, the surgical procedure as the between subject variable, and all clinical indices and Barratt's score as the independent variable, was calculated.

8.2.2 Results

Demographics

The 37 patients had a mean age of 48.65 (SD=11.83) years-old. Thirty-two were female with a mean BMI of 45.28 (SD=11.60) and 5 males with a mean BMI of 44.64 (SD=12.90). Six patients underwent a laparoscopic band, 17 a gastric by-pass and 14 a sleeve gastrectomy. Pre-operatively all three surgical groups were similar at baseline in age (F (2,36)= 2.25, p=0.12)), initial BMI (F (2,36)=1.65, p=0.21) and Total BIS score (F (2,36)=0.39, p=0.68), using a one-way ANOVA.

Weight loss

At a mean time of 11.4 (± 1.5) months follow-up those in the gastric by-pass group showed the greatest percentage fall in BMI of 27.4 (± 5.6), followed by those who had the sleeve gastrectomy, with a fall in BMI of 22.10 (± 22.11) percent and those with the least change in BMI were gastric band group with a reduction in 14.77 (± 6.2) percent (F (2,34)=5.27, p=0.01).

BIS

Similarly the total BIS's score was greatest in those having a gastric by-pass (66.36, SD=26.89), followed by the gastric sleeve group (63.76, SD=10.20) and was least in the gastric band group (60.67, SD=13.57). All other sub traits of the BIS are shown in Table 9.1. There was no difference statistically between the groups (p=0.68). The

Total BIS scores were normally distributed and a Pearson Correlation found the Total BIS's score to correlate significantly with the number of psychiatric comorbidities (r=0.37, p=0.03). Of the sub traits, Attentional Impulsivity was the only dimension to significantly correlate with the number of psychiatric diagnosis (r=0.42, p=0.009). The Attentional dimension was also positively correlated with whether an individual smoked or not (r=0.40, p=0.01). Neither the Motor nor the Non-planning, second order sub traits correlated with any of the clinical parameters. Similarly, none of the first order sub traits correlated significantly with the clinical parameters.

Table 8-1 Table comparing the difference in BIS scores between the three surgical groups

	Gastric Band	**Gastric Sleeve**	**Gastric By-pass**	**Significance**
Initial BMI	42.1 (SD 19.9)	42.7 (SD 8.3)	49.5 (SD 10.1)	0.12
End BMI	36.2 (SD 18.2)	33.4 (SD 8.3)	36.1 (SD 8.7)	0.15
Age	40.3 (SD 12.8)	51.8 (SD 12.7)	48.4 (SD 8.9)	0.21
Percentage change in BMI	14.77± 6.17	22.10 ± 22.11	22.92 ±9.01	**0.01**
Total BIS's score	60.67 ± 13.57	63.76 ±10.2	66.36 ± 26.89	0.68
Second Order Subtraits				
Attentional	18.50 ±4.55	17.88 ± 3.97	19.92 ± 7.37	0.60

Motor	21.00 ± 8.69	22.76 ± 5.70	23.2 ± 9.97	0.85
Non-Planning	21.67 ± 6.71	23.12 ± 5.61	23.21 ± 9.97	0.88
First Order Subtraits				
Attention	14.17 ± 6.15	11.59 ± 2.96	14.36 ± 3.97	0.13
Cognitive Instability	8.33 ± 2.25	7.00 ± 2.65	7.86 ± 3.39	0.55
Motor	17.00 ± 6.75	15.88 ± 3.90	16.57 ± 4.43	0.85
Perseverance	9.17 ± 4.40	7.88± 2.87	10.57 ± 4.85	0.19
Self-control	13.5± 4.42	12.18± 3.52	11.79± 3.51	0.63
Cognitive Complexity	10.83 ± 3.6	12.59± 3.04	13.14± 2.71	0.30

Predictors of weight loss

The pre and post BMI as the independent variables of a repeated measures GLM found only the Motor component (first order sub strait) of the BIS to be a significant predictor of a reduction in BMI at one year post-operatively, with all surgical groups combined (Wilks' Lambda= 0.84, F (1,24)=4.7, p=0.04). Attention (Wilks' Lambda= 1.0, F (1,24)=0.27, p=0.61), Cognitive Instability (Wilks' Lambda= 0.99, F (1,24)=0.06, p=0.81), Perseverance (Wilks' Lambda= 0.93, F (1,24)=1.80, p=0.19), Self control (Wilks' Lambda= 0.95, F (1,24)=1.19, p=0.29) and Cognitive

Complexity (Wilks' Lambda= 1.00, F (1,24)=0.13, p=0.72) did not predict a reduction in BMI. Of the clinical factors, as expected, the procedure type was the only significant predictor of weight loss (Wilks' Lambda= 0.75, F (1,24)=3.97, p=0.03). Age (Wilks' Lambda= 0.92, F (1,24)=2.17, p=0.15), sex (Wilks' Lambda= 0.90, F (1,24)=0.02, p=0.12) and the presence of a psychological diagnosis (Wilks' Lambda= 1.00, F (1,24)=0.32, p=0.88) did not predict weight loss at one-year follow-up.

8.2.3 Discussion

The interest in psychological predictors of weight loss has increased due to the realization that the rapid rise in obesity over the last decades cannot be simply explained by changing genetic factors. All three second order factors of impulsive behaviour (attentional impulsiveness, motor impulsiveness and non-planning impulsiveness) captured by the BIS have been associated with unhealthy eating in normal weight adults and in those with Binge Eating Disorder (Scarborough et al., 2011). To date, mostly the BIS scores and second order scores have been used for analysis, with less emphasis on the first order subtraits (Stotenberg, Baiten, Birgenheir, 2007). The six first order subtraits represent the broad nature of impulsivity and attempt to record the construct at its purest form. From this small pilot study there is evidence to support the use of first order sub traits as the motor impulsivity dimension was found to be a predictor of weight reduction at one-year follow-up. The initial definition of this primary factor by Barratt was 'to act at the spur of the moment' and is represented by the seven following questions (see Table 9-2).

Table 8-2Questions composing the primary motor impulsivity factor

1	I do things without thinking
2	I make up my mind quickly
3	I am happy-go-lucky
4	I act on impulse
5	I act on the spur of the moment
6	I buy things on impulse
7	I spend or charge more than I earn

Five of the seven statements (1, 2, 4, 5 and 6), when answered positively, can be conceptualised by poor inhibitory control. Therefore one would expect to be studies supporting the correlation between performance on the BIS and behavioural measures. This is not the case and, to date, there is no evidence for any significant correlation between any of the BIS questionnaire subtraits and behavioural measures of pre-potent response inhibition (Aichert et al., 2012). These authors found a significant association of BIS impulsivity with commission errors on the go/no-go task and directional errors on the antisaccade task but no association with the Stop Signal Task.

Although the total BIS score did not correlate with BMI it did correlate significantly with the number of psychiatric illness, either anxiety or depression, during the lifetime. This finding is to be expected as the questionnaire was developed based on psychopathology (Patton, 1995). Twenty-two of the 37 patients enrolled in the study had at least one diagnosis of either anxiety or depression during their lifetime, supporting the high psychopathology rates in this patient group. Barratt (1965) described impulsivity to be orthogonal to anxiety. This may explain why in this small population where a large proportion of patients who may have had an anxious temperament there was no correlation between impulsivity scores and BMI. When proportion of psychiatric diagnosis in the bariatric group was also significantly higher than that found in the adult lifestyle intervention group (40%).

Obesity has been described in terms of food addiction (Volkow & Wise, 2005), a condition characterized by overeating. Individuals with food addiction exhibit psychological disturbances such as depression, which was present in high proportions in the current study group. More so, food addiction is associated with a cluster of psychological symptomatology including: Binge Eating Disorder (BED) and Attention-Deficit Hyperactivity Disorder (ADHD), conditions for which impulsivity is part of the diagnostic criteria (Davis et al., 2011). Early experiments have shown that anxious individuals may in fact act in an impulsive manner given a condusive and stressful environment (e.g., Wallace, Newman, & Bachorowski, 1991).

8.3 Study 2

8.3.1 Method

Patients attending either a multidisciplinary information session or out-patient clinic at the Imperial Weight Management Centre were recruited with informed consent into the trial over a four month period from January to April 2013. All enrolled in the study were interviewed by a psychologist or psychiatrist to exclude organic mental disorders such as personality disorders, schizophrenia and BED. Anxiety and depression were not used as an exclusion criteria, as there was a high prevelance of these conditions in study 1. Those with a formal diagnosis of Binge Eating Disorder defined as having two main characteristics: firstly, consumption of a large amount of food relative to the circumstances; and, secondly, the experience of loss of control; were excluded from the study. Participants were invited to attend behavioural testing on an outpatient basis in a silent room invigilated by a single researcher. BMI was objectively measured preoperatively and at 6 month post-operatively. Prior to starting the surgical care pathway, which includes a strict diet, patient's dietary status was established by a single question: Are you trying to lose weight at the present time? This has been shown to be a direct measure of dieting status.

Behavioural Tasks

All computerised tasks were administered on the same occasion.

Temporal Discounting Task and Stops Signal Task

These tasks are described in detail in the methodology chapter.

Cambridge Gambling Task (CGT)

Decision making deficits and risk taking can be characterized using the Cambridge Gambling Task (Rogers et al., 1999), a decision making task that has previously been found to be sensitive to many pathological states including: ADHD (DeVito et al., 2008), borderline personality disorder (Bazanis et al., 2002), Huntington's disease (Watkins et al., 2000). It had also shown how gambling preferences change with increasing age (Deakin, Aitken, Robbins, & Sahakian, 2004). On each trial, a row of ten boxes are presented across the top of the screen, some of which are red others are blue. At the bottom of the screen two rectangles are presented, containing the words 'red' and 'blue'. The subject must guess whether a yellow token is hidden in a red or in a blue box and wager a proportion of their points (5%, 25%, 50%, 75% or 95% of current points) displayed in either ascending or descending order. If the correct colour is chosen, the subject will gain points and if an incorrect colour is chosen, the point will be deducted. The ascending mode was always tested first followed by the descending mode. The stakes rise in the ascending mode, whereas in the descending mode the stakes decrease. Therefore, the CGT is able to dissociate risk taking from impulsivity as in the ascending mode the subject has to exhibit patience in order to place a higher more risky bet. Three components of the CGT were recorded in order to capture measurements of impulsivity: (i) delay aversion/impulsivity index, the difference in risk taking scores between the ascending and descending condition. Consistently early bets (e.g., 95% points descending -5% points ascending) produce a high impulsivity index; (ii) deliberation time, the mean latency time to making a decision; and (iii) overall proportion bets, the mean proportion of the current total points that the subject chooses to risk on each trial regardless of the likely outcome.

Socioeconomic status

The socioeconomic status was confirmed for each patient by use of their post-code. Participants were divided into either the ABC1 groups, which is the higher social classification group or C2DE, which the lower tier group.

Eating Disorder Questionnaires

Questionnaires were used to measure dietary behaviour in an attempt to capture dietary restraint. Dietary restraint is defined as the intention to restrict food intake in order to control body weight (Herman & Mack, 1975). The construct of dietary restraint has been theorized to be a psychological determinant of overeating (Ruderman & Wilson, 1979), Binge Eating (Ruderman, 1986) and Bulimia Nervosa (Polivy & Herman, 1985). The dietary restraint hypothesis states that there is a causal relationship between dietary restraint and overeating. Laboratory studies have supported the finding that those defined as high in dietary restraint often overeat in response to a pre-load. This is a form of counter-regulation (Lowe & Levine, 2005; Polivy, 1996).

Eating Disorder Examination (EDE-Q)

EDE-Q is a self-report version of the Eating Disorder Examination (EDE; Fairburn, Cooper, Doll, & Davies, 2005). Performance on the Eating Disorder Examination Questionnaire has been extensively studied, both in isolation and in comparison with the Eating Disorder Examination Interview (Black & Wilson, 1996; Carter, Aime, & Mills, 2001; Fairburn & Beglin, 1994; Grilo, Masheb, & Wilson, 2001; Kalarchian, Wilson, Brolin, & Bradley, 2000; Luce & Crowther, 1999; Passi, Bryson, & Lock, 2003; Rizvi, Peterson, Crow, & Agras, 2000; Wilfley, Schwartz, Spurrell, & Fairburn, 1997). It is a 41 item of self-report questionnaire and it contains four subscales and a global score. The four subscales are: restraint, eating concern, shape concern and weight concern. It queries about behaviour over a 28-day period and retains the scoring system of 0-6. With a zero meaning "not having engaged in the behaviour at all", 1 for "1-5 days", 2 for "6-12 days", 3 for "3-15 days", 4 for "16 to 22 days", 5 for "23-27 days" and 6 for "everyday". The dietary restraint subscale was the measure of interest. In common with the other subscales including the global score, the dietary restraint subscale score is the mean of the items rated.

Dutch Eating Behaviour Questionnaire (DEBQ)

The DEBQ (Van Strien, Frijters, Bergers, & Defares, 1986) was used to measure emotional eating (eating in response to aroused emotional states), external eating (eating in response to the presentation of food regardless of hunger) and dietary restraint (intentional control of food intake). The DEBQ is composed of 33 items, all based on a 5-point scale ranging from 'never' to 'very often'. The test has high internal consistency with a reliability between 0.80 and 0.95 and factorial validity.

The Positive and Negative Affect Schedule (PANAS)

The PANAS assesses the subjective experience at a given time (Watson, Clark, & Tellegen, 1988). This is a 20-item self-report measure with subjects rating the extent to which they feel a particular emotion on a 5-point scale (1 for "not at all" to 5 for "strongly"), over a given period of time. The inventory was developed on a sample of undergraduate students and has been validated with adult populations, comprising two mood scales; one measuring positive affect and the other measuring negative affect. The authors have used the scale to measure "affect at this moment", "today", "the past few days", "the past week", "the past few weeks", "the past year" and "generally". Watson and colleagues (1988) reported a Cronbach's α coefficient for the various time reference periods ranging from 0.86 to 0.90 for the positive affect scale and 0.84 to 0.87 for the negative affect scale. Measures of general distress, and dysfunction, depression and state anxiety are more highly correlated with the Negative Affect scale than the positive affect scale.

Three-Factor Eating Questionnaire (TFEQ)

The TFEQ is a self-reported questionnaire developed to measure cognitive and behavioural components of eating (Stunkard & Messick, 1985). The instrument contains 36 items with a yes/no response format, 14 items on a 1-4 response scale and one vertical rating. All item responses are dichotomized and aggregated into three scales. Cognitive Restraint (21 items), Disinhibition (16 items) and Hunger (14 items). Cognitive Restraint is designed to measure dietary restraint, that is, control over food intake in order to influence to body weight and body shape. Disinhibition measures episodes of loss of control over eating, while the Hunger scale concerns subjective feelings of hunger and food cravings.

8.3.2 Results

Patients

Overall, all 45 patients screened underwent bariatric surgery. Twenty-five of the 45 patients had a gastric bypass, with a mean BMI of 41.8 (SD=5.7) and a mean age of 39.0 years-old (SD=13.4). The sleeve gastrectomy group were significantly older [mean age of 49 years-old (SD=10.4) with a mean BMI of 47.2 (SD=5.9)]. The difference between groups are summarised in Table 9-3. The sleeve gastrectomy group showed a reduction in percentage BMI of 14.1% (SD=4.7), which was significantly less than the 25% (SD=4.1) reduction in BMI in the gastric by-pass group (p=0.0001). There was no difference between the number of diagnosis of psychiatric conditions between both groups (p=0.23). There was no correlation between any of the behavioural measures of impulsivity and comorbidities or the number of psychiatric or medical diagnosis between groups.

8.3.2.1 Impulsivity Baseline

Behavioural measures

At baseline before surgical intervention there was no difference between the SSRT (169. 7ms (SD=44.5) vs 204.0 ms (SD=81.7), p= 0.8) and the Temporal Discounting Constant (0.42 vs. 0.41, p=0.9) between the sleeve gastrectomy and gastric by-pass groups respectively. The CGT paramenters were also similar between both groups (see Table 9-3).

Table 8-3. Difference in behavioural measures between the two surgical groups

	CGT Delay	CGT Latency	CGT Proportion	Discount rate	SSRT
Sleeve gastrectomy	0.48 (SD 0.17)	2692.8 (SD 1128.8)	0.55 (SD 0.1)	0.41 (SD 0.4)	204.0 ms (SD 81.7)
Gastric By-pass	0.43 (SD=0.31)	2429.8 (SD=1128.8)	0.53 (SD=0.1)	0.42 (SD=0.4)	169.7 ms (SD=44.5)
P-value	0.51	0.47	0.56	0.93	0.08

Questionnaires

There was no difference in either positive (29.5 (SD=7.3) vs 23.4 (SD=8.7), p=0.21) or negative (23.4 (SD=8.7) vs. 23.0 (SD=7.8), p=0.86) affect between the gastric by-pass group and the sleeve gastrectomy group as measured by the PANAS questionnaire. The restraint component of the EDE-Q (2.5 (SD=1.0) vs. (2.4 (SD=0.92), p=0.78) and the DEBQ (31.2 (SD=7.7) vs. 27.7 (SD=8.0), p=0.14) were also unable to differentiate between groups. However, the restrain component of the TFEQ-R found those in the sleeve gastrectomy group to have greater restraint (15.1 (SD=3.7) than the gastric bypass group (10.6 (SD=2.5)), p= 0.0001). The sleeve gastrectomy group were also found to have greater scores for the first order attention subtrait of the BIS (14.9 (SD=2.7) vs 12.0 (SD=2.7), p=0.001).

8.3.2.2 Correlation between behavioural measures

The SSRT correlated significantly with the patient BMI (r= 0.4, p=0.01). None of the temporal discounting or CGT paramenters showed any relationship to the patients'

BMI. The SSRT also correlated significantly with the delay aversion component of the CGT (r=0.3, p=0.03). This meant that those who were more impulsive during the Stop Signal Task exhibited a greater proportion of impulsive bets as opposed to showing self-control and waiting for larger bets. The delay aversion component of the CGT also correlated with the mean latency time to make a decision (r=-0.3, p=0.03) and total points the subject chooses to risk (r=0.4, p=0.009) during the task (see Table 9-4).

8.3.2.3 Socioeconomic status and Temporal Discounting

Using a one-way ANOVA with the Temporal Discounting Constant (TDk) as the dependent variable and socio-economic status as the independent variable, the socioeconomic status was not associated with an individuals discounting constant (F(1,44)=1.90, p=0.75).

Table 8-4. Correlation of the three behavioural measures of impulsivity.

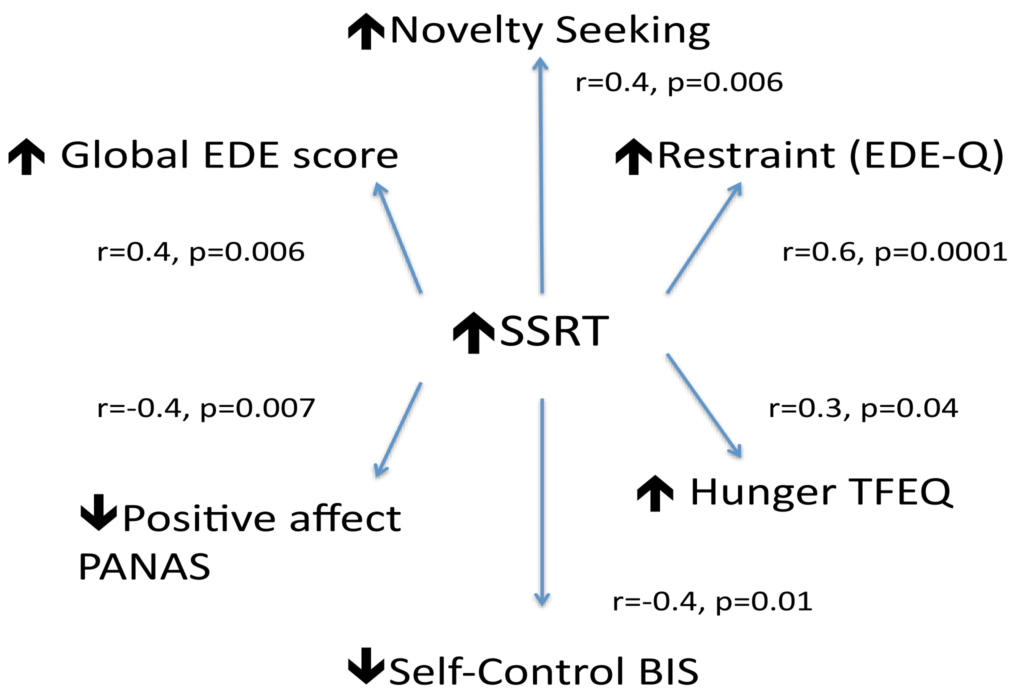
	SSRT	TDk	CGT Delay	CGT Latency	CGT Proportion
SSRT		-0.078	**0.323***	-0.19	0.26
TDk			-0.05	-0.07	0.05
CGT Delay				-0.33*	0.39**
CGT Latency					-0.11
CGT Proportion					

*p<0.05, **p<0.001

8.3.2.4 Correlation between behavioural measures and questionnaires

The SSRT correlated strongly with the restraint component of the EDE questionnaire (r=0.6, p=0.0001) and the overall global EDE score (r=0.4, p=0.006). There was a negative correlation with the positive affect of the PANAS questionnaire (r=-0.4, p=0.007) but no association with the negative affect (r=-0.2, p=0.26). The only component of the TFEQ scale to show correlation with the SSRT was the hunger component (r=0.3, p=0.04). Only the self-control component of the Barratt's Impulsivity Scale was found to be negatively correlated with the SSRT (r=0.4, p=0.01). The Novelty Seeking component of the TCI was found to be positively correlated with the SSRT (r=0.4, p=0.006). The Temporal Discounting Constant did not correlate with any of the questionnaire measures of impulsivity. The proportion component of the CGT correlated negatively with the Hunger scale of the TFEQ (-0.3, p=0.047) and the latency period of the CGT correlated positively with the Restraint component of the TFEQ (0.4, p=0.006). (See figure 9-2)

Figure 8-2 Relationship between the SSRT and various eating behaviour questionnaire measures



8.3.2.5 Impulsivity as a predictor of weight reduction

A stepwise regression using the percentage change in BMI as the dependent variable and entering age, change in SSRT, change in temporal discounting, initial discounting constant and finally the initial SSRT was conducted. The overall model was significant (R^2=0.375, F(1,44)=7.2, p= 0.02). The initial Temporal Discounting

Constant was found to a predictor of the percentage weight reduction (β=11.54, t=2.7, p=0.02). The Change in SSRT was also significant (β=0.43, t=2.2, p=0.05).

8.3.3 Discussion

The study found inhibitory control to be a predictor of weight loss in patients undergoing bariatric surgery. These results are consistent with the findings from the adolescent residential lifestyle camp. From these findings it appears that the SSRT is the only robust predictor of weight reduction. There are discrepancies between how well this task correlates with measures of the BIS. In the pilot study, the first order subtrait of motor impulsivity was able to predict weight loss regardless of the surgical procedure at one year. However, in study 2, the motor subtrait was no longer a predictive of weight reduction, neither did it correlate with the SSRT. In Study 2, the SSRT was found to correlate more with the self-control component of the BIS and Novelty Seeking of the TCI.

8.3.4 Overall Discussion

In the bariatric population tested the BIS was able to identify components at lower levels of abstraction, which are commonly not measured. The lower order abstractions are likely to represent the subtrait in its purest form without overlap of other components. This provides a narrow construct on which to base potential predictors.

Studies investigating non-clinical samples have shown different associations between the BIS and measures of eating behaviour. Lyke & Spinella (2004) found a small positive correlation between the Hunger sub-scale of the TFEQ and the Attentional Impulsivity. In addition, both the Attentional and Motor Impulsivity were correlated with disinhibition. Recently, Koningsgruggen and colleagues (2013) showed the attentional subscale of the BIS to be positively correlated with the concern for dieting subscale of the Restraint Scale (Herman & Mack, 1975). The study also found the BMI to be positively correlated with the Motor Impulsivity subscale. Nolan (2012), however, did not find any correlation between BMI and the BIS but when asked to rate the pleasantness of eating different foods on a visual analogue scale the Attentional Impulsivity subscale positively correlated with the pleasantness of eating high calorie foods.

Spinella (2007) developed a short form of the BIS-11 containing 15 questions. Scores of the short form are highly correlated with the full version (r=0.94). The shorter version has been correlated with various questionnaires measuring constructs of overeating. The Attentional Impulsivity scale in particular has been shown to be correlated with the morbidly obese patient opting for bariatric surgery.

Table 8-5 Correlations between the short form BIS, BMI and self-report measures of overeating in bariatric patients (Meule, Heckel & Kubler, 2012).

	Barrett Impulsivity Scale – short form			
	Attentional	Motor	Non-planning	Total-scores
BMI (kg/m2)	-0.23	-0.03	-0.24	-0.22
Eating Disorder Examination-Questionnaire-objective binge episodes	0.38*	0.04	0.10	0.23
Food Craving Questionnaire-Trait	0.45*	0.10	0.09	0.27
Yale Food Addiction Scale-symptom scale	0.39*	0.11	0.11	0.26

*P<0.05

Novelty seeking was found to be related to behavioural inhibition of the form of the SSRT. According to Cloninger (1997), Novelty Seeking is hypothesized to be a heritable tendency towards intense exhilaration or excitement in response to novel stimuli or cues for potential rewards or potential relief of punishment, which leads to frequent exploratory activity in pursuit of potential rewards. Each of Cloninger's temperaments is related to one of three brain systems: behavioural activation, behavioural inhibition and behavioural maintenance. Although Novelty Seeking correlated with SSRT, which is a measure of behavioural inhibition, Novelty Seeking itself is traditionally related to behavioural activation whereas Harm Avoidance is represented by the behavioural inhibition system. Therefore, those who reported exhibiting the greatest amount of restraint over a longer period of time (up to 28 days) were significantly more impulsive on the Stop Signal Task. This is not an expected finding, as one would expect more impulsive patients to show less restraint. There could be two reasons for this; firstly both the Stop Signal Task and measures of restraint may be orthogonal measures of impulsivity. Secondly, prolonged restraint can also manifest as impulsive performance when tested objectively.

Global EDE scores correlated positively with the SSRT. The EDE-Q is one of the preferred questionnaires for the diagnosis of eating disorders and is a modification of the EDE which is regarded the gold standard assessment for Bulimia Nervosa symptomatology (Garner, 2005). The EDE was an interview questionnaire and in the correct hands allowed for investigator-provided expertise and structure. Although there have been some discrepancies between the EDE and the EDE-Q subscales regarding weight and shape concern, the subscale of Dietary Restraint has always been consistent (Passi et al., 2003; Polivy & Herman, 1985). Therefore, its association with SST is potentially a robust finding. These findings can be explained by 'Restraint Theory', which asserts that dieting leads to overeating and bingeing (Polivy & Herman, 1985), which are associated with poor self-control and overeating. Restraint theory postulates that dieting and dietary restraint are considered equivalent and disinhibition of eating control among dieters is considered an inevitable consequence of their dietary restraint (Heatherton, Herman, Polivy, King, & McGree, 1988). Although the study did not use a measure of eating habit the participants did respond impulsively using an objective behavioural task.

Chapter 9 Explanatory validity of impulsivity measures: Pharmacological manipulation of impulsivity.

9.1 Introduction

Impulsivity has been shown to both predict and be potentially modifiable with weight reduction. In a recent study, Mackillop and colleagues (2014) suggest that impulsive behaviour may not necessarily be associated with obesity but impulsive behaviours can lead to food addiction, which in turn may be the driving force behind higher BMI (Murphy, Stojek & MacKillop, 2014). In humans, palatable food is associated with dopamine release in mesolimbic regions similarly found in response to the administration of many addictive substances (Volkow & Wise, 2005). Additionally, obesity has been linked to reduce dopamine D_2 receptors, also present in individuals with addictions and subjective reward reported from eating palatable food is correlated with the resulting degree of dopamine release (Stice, Spoor, Bohon & Small, 2008; Wang et al., 2001).

In an attempt to delineate the neuronal pathways associated with impulsivity and obesity, the action of two clinically approved pharmacological agents for impulsive conditions was tested (Maziade et al., 2009; Schmaal et al., 2013; Wehmeier et al., 2012). Both modafanil and atomoxetine have been licensed for use in adults and children with Attention Deficit/Hyperactivity Disorder, a condition characterized by deficits in response inhibition.

9.1.1 Modafinil

Modafinil has a clinical profile unique to conventional stimulants and is approved by the FDA for use in narcolepsy, shift work disorder and excessive daytime sleepiness (FDA). Modafinil has been shown to enhance cognition in a variety of disorders such as alcohol dependence, schizophrenia (Hunter, Ganesan, Wilkinson, & Spence, 2006), ADHD ((Turner, Clark, Dowson, Robbins, & Sahakian, 2004) and in healthy individuals (Greely et al., 2008; Joos, Docx, Schmaal, Sabbe, & Dom, 2010). The mechanism of action of modafinil is unclear. It is not thought to act through the cathecholamine pathways as other psychostimulants such as amphetamines and methylphenidate (Biederman & Pliszka, 2008; Tahsili-Fahadan, Carr, Harris, & Aston-Jones, 2010). Modafinil has been shown to have an effect on response inhibition that is dependent on baseline impulsivity, only being effective in those with poor response inhibition. This was demonstrated by inducing better performance on the Stop Signal Task in pathological gamblers who displayed high levels of self-reported baseline impulsivity (Zack and Poulos, 2009). Similar results have been shown in other drug dependent groups including demonstrating promising treatment effects in cocaine and methamphetamine dependent patients with significant more negative urine samples (Dackis et al., 2005; Shearer et al., 2009), longer period of abstinence (Anderson et al., 2009), a reduction in substance use (Hart et al., 2008) and less craving (Hart et al., 2008; Anderson et al., 2009).

9.1.2 Atomoxetine

Atomoxetine is a selective norephinerine reuptake inhibitor and is a non-stimulant based drug of choice for the treatment of Attention Deficit Hyperactivity Disorder (Michelson et al., 2003). Unlike modafinil, due to its mechanism of action, atomoxetine is helpful in patients with depression, especially when ADHD occurs co-morbidly with depression (Spencer et al., 2006).

In a study by Spencer and Colleagues (2006), 22 adults with ADHD were entered into a double-blind RCT with atomoxetine. Neuropsychological tests covered domains of inhibition (Stroop), sustained attention (auditory continuous performance), attentional set shifting (Wisconsin Card Sort) and visual memory (Rey-Osterrieth Complex Figure). Significant improvements were detected following a 3-week atomoxetine treatment on the Stroop Test alone, which the authors suggested was indicative of improvements in inhibitory capacity. Very few studies have reported the effects of a single dose of atomoxetine on inhibitory control. Chamberlain and colleagues (2007) re-reported improved response inhibition on the Stop Signal Task following a single dose of atomoxetine (60mg), compared to the administration of placebo or the SSRI citalopram in healthy male volunteers.

In addition to reports of improving inhibitory control, atomoxetine was shown to reduce the frequency of binge eating episodes, BMI and scores on the Hunger subscale of the TFEQ in participants with BED (McElroy et al., 2007). In addition to its short term effects, a prolonged dose of atomoxetine was found to reduce weight in obese women as part of a 10-week RCT (Gadde, Yonish, Wagner, Foust, & Allison, 2006).

The study aimed to examine the effect of both modafinil and atomoxetine on the cognitive performance of the two behavioural tasks in healthy adult volunteers. Both pharmacological agents are thought to have a similar cognitive profile with regard to the Stop Signal Task, but with unique biological mechanisms of action. Using both agents and comparing the performance on the Temporal Discounting Task permits inferences regarding any common neurochemical mechanisms between both constructs.

This is important to obesity research and intervention as eating behaviours are to large extent shaped by experience, the cognitive processes involved in regulating food intake include reward-based learning (Petrovich, Holland, & Gallagher, 2005) as well as top-down control over such learned responses in the service of more abstract goals, such as to maintain a healthy weight (Hare, Camerer, & Rangel, 2009).

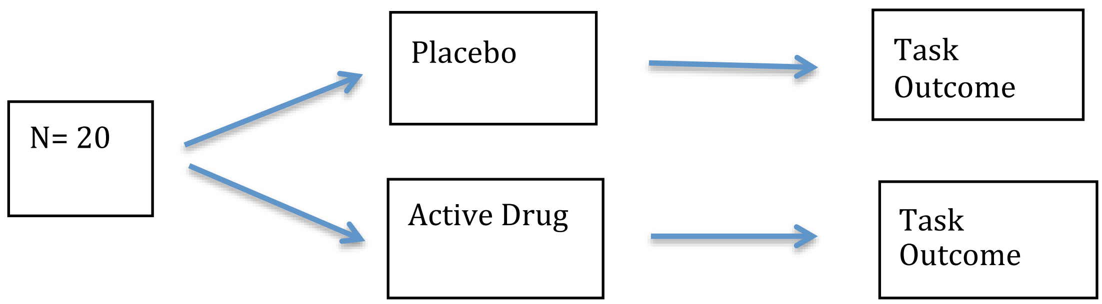
9.2 Method

9.2.1 Subjects and procedures

Forty healthy young male adult volunteers taking no regular medication were recruited by advertisement at Imperial College. Exclusion criteria included any psychiatric illness, visual, auditory or motor impairment; cardiac or neurological illness, score greater than ten on the Epworth Sleepiness Scale; answer "yes" to more than two questions on the CAGE questionnaire; have a history of drug or alcohol addiction; or drink more than 8 cups of coffee per day. All participants were advised to stay free from caffeine and alcohol for at least 12 hours before commencing the experiment. The study had approval from the Imperial College Ethics Committee and all participants gave informed consent before testing.

A double blind randomized controlled trial was used with 20 participants randomized to receive either a single oral dose of a lactose placebo or one of the test substances (200mg modafinil or 60 mg atomoxetine). A between subject was avoided in order to eliminate any potential learning bias.

Figure 9-1 Illustration of the randomisation process



9.2.2 Physiological measures

Subjects were invited to attend the study centre on two separate occasions at least seven days apart. A health questionnaire was completed on the first visit. This allowed them a chance to consider their participation into the study and their family practitioner to be informed. On the second visit, participants prior to administration of the drug completed the CAGE questionnaire, the Barratt's Impulsivity Index, Cloninger's Temperament and Character Inventory and the National Adult Reading Test (NART). The blood pressure and pulse were taken whilst completing the questionnaires and repeated at 12 minute intervals throught out the experiment and at the end of the testing.

9.2.3 NART

All assessments of cognitive function correlate to a varying degree with general intellectual ability. Therefore, knowledge of participants premorbid IQ was essential.

The National Adult Reading Test (NART) is simple to administer, taking only around 10 minutes to complete, while also being highly predictive of intelligence in both clinical and non-clinical populations. Subjects are asked to read aloud a set of 50 words written on a test card, which are marked as either correct or incorrect according to their pronunciation. This score is then used to calculate an estimate of premorbid IQ.

9.2.4 Epworth sleepiness scale

The Epworth sleepiness scale assesses chronic sleepiness by determining the subject's propensity to fall asleep in a range of environmental conditions. With respect to the recent past, participants are asked to “rate their chance of dosing” on a scale of 0-3 (0 = “would never doze”, 1 = “slight chance of dozing”, 2 = “moderate chance of dozing”, 3 = “high chance of dozing”) in eight conditions including: “sitting and reading”, “lying down in the afternoon when circumstances permit”, and “in a car while stopped for a few minutes”. 0-5 is considered normal, 6-10 is considered to represent mild sleepiness, 11-15 is considered to represent moderate sleepiness, and >16 is considered to represent severe sleepiness. Subjects with scoring greater than ten were excluded from the study.

9.2.5 Visual Analogue Scale

Subjects rate how they feel by making a mark on a continuous line linking two opposing conditions (Bond & Lader, 1974). 16 dimensions are assessed: alert-drowsy, calm- excited,strong-feeble, muzzy-clear headed, well coordinated-clumsy, men- tally slow-quick witted, lethargic-energetic, contented-discontented, troubledtranquil, tense-relaxed, attentive-dreamy, incompetent-proficient, happy-sad, antagonistic-amicable, interested-bored and withdrawn-gregarious.

Behavioural measures

The Stop Signal Task and Temporal Discounting Task are discussed fully in the Methodology Chapter.

9.2.6 Statistics

This study will follow a randomised, placebo controlled, balanced design. Participants will receive 200mg modafinil, or a lactose placebo. Data for questionnaires (NART, VAS ESS) were analysed using repeated measures ANOVAs with allocation arm as a between subjects factor and drug condition as a within subjects factor. Power analysis reveals that a total sample size of around N=20 will be required to achieve 90% power at alpha 0.05 for an effect size of 0.25. No interim analysis will be performed and all randomised subjects will be included in the analysis.

The SSRT and Temporal Discounting between groups were analysed using a two-tailed t-test to compare means.

9.3 Results

9.3.1 Modafinil

9.3.1.1 Baseline

A one way ANOVA found there no difference in the NART score between the modafinil [45.5 (SD=1.7)] and control group [46.0 (SD=3.9)], F (1,38)=0.29, p=0.57. Before the study, all subjects score 0-5 on the Epsworth Sleepiness Scale. There was no difference between the Epsworth Sleepiness Scale between the modafinil (Mean score=3.2 (SD=1.2) and control group (Mean score= 3.1 (SD=1.1), F (1,38)=0.18, p=0.68. The only difference between both groups on the Visual Analogue Scale was in the tense-relaxed question, with those in the modafinil arm (Mean score=7.9 (SD=0.66) being more relaxed than in those in the control arm (Mean score=7.13 (SD=1.15), F(1,38)= 5.9, p=0.02.

9.3.1.2 SSRT

Subjects receiving modafinil [128.1 (SD=31.6)] had a significantly lower stop signal reaction time than the control group [156.4 (SD 34.9)], p=0.03. **Figure 9.1**.

9.3.1.3 Temporal Discounting Constant

There was no significant difference between the Temporal Discounting Constant (TDk) between those in the modafinil group [0.35 (SD=0.37)] and the control group [0.31 (SD=0.36)], p=0.50.

9.3.2 Atomoxitine

9.3.2.1 Baseline

A one way ANOVA found no difference in the NART score between the atomexetine [43.6 (SD=2.1)] and control group [23.9 (SD=.8)], F(1,38)=0.52, p=0.48. Before the study, all subjects score 0-10 on the Epsworth Sleepiness Scale. There was no difference between the Epsworth Sleepiness Scale between the modafinil [Mean score=5.0 (SD=1.4)] and control group [Mean score= 5.2 (SD=1.2)], F (1,38)=0.38, p=0.54. There was no significant difference between both groups on any of the Visual Analogue Scales.

9.3.2.2 SSRT

There was no difference between the atomoxetine and control group with regard to the SSRT [173.4 ms (SD=57.4) versus 159.1 ms (SD=44.3), t=0.7, p=0.2] .

9.3.2.3 Temporal Discounting Constant

There was no difference in the TDk between the atomoxetine and control group [0.49 (SD=0.17) versus 0.52 (SD=0.10) t=-1.3 , p=0.2].

9.4 Discussion

Modafanil but not atomoxitine was found to reduce the deficits in inhibitory control. Functional MRI studies have isolated deficits in response inhibition to the right frontal cortex (Aron et al. 2003). The action of modoafanil as demonstrated by *in vivo* and *in vitro* studies have suggested a high affinity for dopamine transport in the brain (Geracitano, Federici, Prisco, Bernardi, & Mercuri, 2004; Hermant, Rambert, & Duteil, 1991; Madras et al., 2006; Mignot, Nishino, Guilleminault, & Dement, 1994). Similar findings have been reported with modafinil enhancing performance on digit span, visual pattern recognition, memory, spatial spanning and stop signal reaction time (Turner, Robbins, Clark, Aron, Dowson & Sahakian, 2003). The same paper found performance of the Stop Signal Task to be dose dependent. These findings support modafinils actions through both memory and cognitive process as opposed to purely enhancing psychomotor performance. In the current study, the effect of latency was not a simple psychomotor effect of the drug. Standard reaction times, as measured by the median 'go' reaction time on the SST, remained unaffected by modafinil.

9.4.1 Incentive salience, addiction and dopaminergic pathways

Incentive salience is a motivational 'wanting' attribute given by the brain to reward predicting stimuli, often causing the stimuli to be highly sought after. According to models of incentive salience, addictive substances modify the dopaminergic mesocorticolimbic system making it hyper responsive to food and drug-associated stimuli. In addition, Goldstein and Volkov (2002) emphasise in their 'impaired response inhibition' and 'salience attribution' model, that addiction is not only characterized by salience attribution to drug-associated stimuli, but that deficits in inhibitory control for conditioned drug response. Both of which contribute to a loss of self-directed behaviour. More recently, Berridge (2007) suggested that a sensitization of the dopaminergic reward system by food and food-associated stimuli might also take place and contribute to obesity.

Neurocognitive agents may used to reduce obesity. In support of the association between obesity, impulsivity and the dopaminergic pathways many studies support modafinil as a weight reducing medication in both the adult and adolescent population (Hart et al., 2006; Henderson et al., 2005; Thase, Fava, DeBattista, Arora, & Hughes, 2006; Vaishnavi et al., 2006; Wigal, Biederman, Swanson, Yang, & Greenhill, 2006). Although, once again, the exact mechanism is unknown and yet unproven by a randomised controlled trial.

9.4.2 Temporal discounting and pharmacomodulation

There was no association between either agent and the Temporal Discounting Constant. To date only d-amphetamine has been shown to reduce delayed discounting in rats (Krebs, 2012). Most of the literature on temporal discounting and pharmacology has been carried out in rat models. In studies using in bred strain of mice showed rats that exhibit high responding in novel environments more readily self-administered drugs than low responders (Belin, Berson, Balado, Piazza & Deroche-Gamonet, 2011). Such high responders also exhibited steeped delayed discounting. In humans, only amphetamines have been shown to reduce delayed discounting to date (Wit, Enggasser & Richards, 2002).

Chapter 10 The development and use of a pre-commitment intervention aimed at reducing impulsivity to support weight loss maintenance in obese adolescents

10.1 Introduction

In order to maximise treatment efficacy, the psychological assessment of obese persons should explore the different facets of impulsivity, for example the stop signal task to assess inhibitory control and the monetary task for temporal discounting. Based on our evaluation both of these facets of impulsivity appear to play a variable role in obesity. Any potential psychological intervention should either target inhibitory control or discounting problems that characterise impulsive behaviours. Two types of interventions must be considered: the first potential intervention for obesity may focus directly on remediation of inhibition, attention and mental flexibility and improving processing resources. These are rather complex interventions and often aimed at targeting a single facet of impulsivity. They may also benefit from interventions that circumvent limited cognitive resources and work on automatic processes. Therapies described to combat automatic behaviours and intrusive thoughts include: mindfulness based interventions, imagery techniques, implementation intention techniques and commitment devices.

10.1.1 Mindfulness based interventions

Mindfulness is the opposite of impulsivity and it is defined as “paying attention in a particular way: on purpose, in the present moment and non-judgemental” (Segal, 2002). The practice of mindfulness is a form of meditation that teaches individuals to observe their thoughts, emotions and bodily sensations without judgement. Mindfulness in eating disorders encourages patients to observe their feelings of hunger and satiety, to recognise these events and voluntarily shifting attention sequentially to visceral sensations instead, such as movements of breathing, sensations in the body, sounds in the environment and the thoughts and emotions that may arise. Early evidence from mindfulness training suggests that it improves self-control of eating with a reduction in binge eating episodes (Kristeller & Hallett, 1999).

10.1.2 Imagery Techniques

Overeating is thought to be triggered by visual or olfactory images of food. It has been proposed that non-food related imagery or adverse imagery may strengthen an individual's thought-control abilities and prevent overeating (Kemps & Tiggemann, 2007). In such experiments, individuals are given a visual or an olfactory imagery task, which trains them to form images which interfere with enticing internally created images of food. The maintenance of these mental images during exposure to food has shown to reduce food desire.

10.1.3 Implementation Intention Techniques

It is thought that episodes of binge eating occur when an individual is under stress and their cognitive resources are depleted. Implementation intentions are *'if-then'* plans which are pre-selected for future situations that are anticipated to be difficult for an individual. Implementation intentions rely on automatic components of self-regulation (Achtziger, Gollwitzer, & Sheeran, 2008; Schweiger Gallo & Gollwitzer, 2007). Therefore, planning in advance the triggering situation, and also, when and how to react to it to produce the desired goal will, in the long term, lead to the automatic initiation and pursuit of long-term goals. The automaticity of the long-term goal directed behaviours hence save valuable self-regulatory resources, which can be channelled into other more worthwhile pursuits. Implementation intentions have been shown to be effective in facilitating the consumption of more fruits and less fat, and in engaging in physical activity (Armitage, 2004; Verplanken & Faes, 1999).

10.1.4 Commitment devices

In addition, many people are aware of their will-power weaknesses and use commitment devices to achieve long-term goals. It has been shown that commitments usually become more effective as the cost for failure increases. A common method for increasing such costs is to make commitments public, since breaking the commitment will lead to significant reputational damage, social disapproval and additional indirect costs (e.g., loss of social support). It is also known that people are willing to use commitment devices (Ashraf, Karlan, & Yin, 2006) and may even impose penalties on themselves for failing to act according to long-term goals (Trope & Fishbach, 2000). In relation to health behaviour, for example, a randomised controlled trial showed that African American women signing a behavioural contract were more likely to reach their exercise goals than a control group where no commitment was made (Williams, Bezner, Chesbro, & Leavitt, 2006). The proposed psychological mechanisms by which commitments may yield successful behaviour change include automatic (and often largely unconscious) impulses to maintain positive self-concept (and self-image), which drives individuals to be consistent with their public promises (Dolan et al., 2012; Reichers, 1985; Werner et al., 1995). This mechanisms resonates with dual-process models of health behaviour that draw upon cognitive and social psychological accounts of information processing (Evans, 2008; Thaler & Sunstein, 2008), which postulate two distinct mental processes: evolutionarily, older processes described as automatic, uncontrolled, effortless, associative, fast, unconscious and affective, and more recent, characteristically human processes described as reflective, controlled, effortful, rule-based, slow, conscious and rational. In summary, commitments allegedly work by 'nudging' the automatic processes, which leads to behavior change (Thaler & Sunstein, 2008).

Pre-commitments were chosen as the psychological intervention of choice as the messages could be tailored to reflect and reinforce the syllabus taught to adolescents in the residential camp. Commitments also allowed for generic messages to be designed in a cost effective manner.

10.1.5 Choice of modality for commitment intervention

Approximately 75% of 12-17 years-old own a mobile telephone, of which 88% of teenage mobile phone users are text messagers (Lenhart, 2010). Text messaging has been shown to be an acceptable medium in which to help foster positive behaviour change (Anthony, Nagel, & Goss, 2010; Franklin, Waller, Pagliari, & Greene, 2006; Hurling et al., 2007; Rodgers et al., 2005; Woolford, Clark, Strecher, & Resnicow, 2010).

Therefore, commitment text messages were used to reduce weight in a group of obese adolescents who had recently attended an intensive weight management programme. Given the evidence that weight regain is prominent after intensive weight management interventions, our prediction was that participants in the commitment condition will succeed to maintain weight loss, while participants in the information condition will regain weight.

10.2 Method

A 12 week randomized controlled trial comparing SMS text messages that provided simple information (13 participants) versus messages incorporating a generic commitment (14 participants) was conducted (i.e., 27 participants were randomized into two arms: *commitment arm* and *information arm*). Figure 7-1 is an outline of the study design and the intervention themes in both arms of the trial. We included in the trial, the participants whose parents provided informed consent from a total of 50 members attending an eight-week residential weight-loss intervention provided by MORELife. All members were funded by the government and referred from low socioeconomic areas. Messages were taken from the lifestyle syllabus followed by participants during their camp stay (Gately et al., 2005). The syllabus provides a framework for education and behavior change by providing physical resources for children, parents and staff delivering the programme. The syllabus consists of a range of food and physical activity behaviours that are related to weight and health of young people: portion control, structured eating, reduced fat and sugar, reduced sweetened beverages, one hour of physical activity involving team sports and exercise routines, reducing sedentary behaviours. Table 10.1 contains an illustration of all the messages sent to participants during the intervention.

The commitment arm received three text messages per week: one asking for a commitment and two further reminders of their commitment. Participants were asked in the messages to reply and commit using a short reply code prefix. In the commitment arm only, if participants replied to the first message the subsequent messages were reminders only. All messages were sent in the late afternoon and were addressed from 'MoreLife'. The first message was received on a Sunday, giving the participant the opportunity to plan ahead for the upcoming week. The information arm received three text messages providing information only and there was no prompt for participants to reply to the messages. All messages were within 160 characters.

Both groups received standardized fortnightly counseling calls lasting on average 10 minutes, which covered progress, social support and any potential barriers to weight loss. A single researcher made calls to all participants. The calls had identical duration and content, the only difference between the phone calls to participants in each arm was that those in the commitment arm were also reminded of their commitment. This extra topic in the conversation added only one additional sentence and aimed to reinforce the commitment for that particular week. Objective measurements of BMI were taken pre and post intervention by the same researcher.

10.3 Results

At the end of the residential camp, 5 males and 8 females with a mean BMI of 32.19 (SD = 7.16) assigned to the information arm. The age-matched commitment arm had 4 males and 10 females with a comparable mean BMI of 31.29 (SD = 8.15). The two groups had equal start in the post-camp intervention as their weight loss during the residential camp (before our intervention began) in both arms were equivalent with a fall in BMI of -2.63 (SD = 1.32) in the informational arm and -2.32 (SD = 1.27) for those assigned to the commitment arm; and the difference between the two groups was not statistically significant in this respect ($t = 0.75$, $p = 0.462$). The participants were available during 72% of the telephone counseling sessions. There was a 60% response rate to the commitment messages; and a survey of all participants revealed the most common reason for not responding to text messages were: not knowing whether to reply or having no credit (17%), or phone not allowing a reply (41%) and the participants having changed their mobile number (40%).

BMI did not change significantly (even though it slightly decreased) in the commitment condition (Mean change (after-before) = -0.12, SD=1.94; Z = -0.41, $p = .341$, one-tailed Wilcoxon signed-rank test), while in the information condition the BMI increased significantly (Mean change (after-before) = 1.06, SD=2.34; $Z = -1.73$, $p = .042$, one-tailed). The BMI change was used as the dependent variable in a linear regression that included as predictors the *condition* (coded as 1=commitment; 2=information), *age*, *gender*, and *initial weight* (at the start of our intervention). The only significant predictors of BMI change were intervention ($\beta = 1.63$, $t = 2.14$; $p = .043$), i.e., being in the information condition increases the weight gain, and initial BMI (β = -0.19, t = 2.92; p = .008), i.e. higher initial weight is associated with smaller regain; while age (p = .220) and gender (p = .608) were not statistically significant predictors. The R^2 was .34. The overall model was also statistically significant (F (4,22) = 2.85, p = .048). To verify the results, especially because the difference between the two intervention conditions, in terms of BMI change, is likely due to the weight re-gain in the information arm, the before-after change scale was converted to binary data using a median split into 'high BMI gain' and 'low BMI gain' (0) participants (i.e., depending on whether they are above or below the median (0.7) change respectively). This binary measure was used as the dependent variable in a logistic regression, which confirmed that the intervention was a significant predictor of BMI regain (β = 2.04, *Wald* = 4.04, *df* = 1, p = .045). The 'odds ratio' Exp(β) for the intervention coefficient was 7.71, which suggests that those who were only given information were almost eight times more likely to regain weight than those who were asked to commit.

10.4 Conclusion

This is the first study to show successful weight loss maintenance in obese adolescents. This result demonstrates that it is feasible to engage adolescents with a commitment technique, as part of a text messaging intervention to support maintenance of weight loss in the community. Pilot studies testing extended therapeutic contact to date have used personalised daily messages providing information regarding lifestyle choices (Joo & Kim, 2007; Shapiro et al., 2008). Developing personalised messages can be costly and labour intensive, if different participants follow varied regimes and set individualised goals, especially when up-scaled to the wider population. The advantage of our intervention is that the messages are generic and therefore should be less costly to implement, because they can be automated and require little labour.

The result reported here is important, because a stable weight, even temporally, in a growing adolescent with obesity is associated with an improvement in cardiovascular risk factors and co-morbidities of obesity (August et al., 2008). To date, no stand-alone weight-loss intervention for children and adolescents using technology, either by e-mail or telephone coaching, has shown to be successful. Lifestyle interventions in general have been shown to be more successful in children and adolescents than in adults.

Temporal discounting is a behavioural economic index of impulsivity (MacKillop, 2013). Commitments in the form of promises to a third party are probably one of the most basic form of commitment devices used (Brocas, Carrillo, & Dewatripont, 2004). The small but significant reduction in BMI in the group receiving commitment messages supports evidence that the initial temporal discounting constant is the best predictor of weight reduction during the maintenance phase of the study.

To conclude, the use of commitment techniques that effect an individual's reputation and decision making pathway may be an efficient mechanism on which to base weight-loss maintenance for adolescents. This has been supported by objective changes in behaviour and weight. In order to reaffirm these findings, a larger study using with a longer follow-up period is necessary with a cost-effective analysis. However, these preliminary findings are encouraging.

Table 10-1 ***Illustration of all the messages sent to participants during the intervention***

Information [Text 1]	Commitment [Text 2]	Monday Reminder [Text 3]	Weekly Reminder [Text 4]
Remember it is important to make sure your food portion size is right for you.	Can you promise to eating 30g of cereal each morning before school (This is the same as one variety pack). Please txt back CAMP followed by Yes or No to 8810.	Hi. I hope you're up for the challenge. If you haven't text back either 'Yes or No' please do today and we can keep on the path to a healthier lifestyle! Txt back CAMP to 8810.	Are you managing to eat cereal in the morning? Text back CAMP followed by yes or no to 8810.
You should try and eat at least 5 fruit and veg a day!	Can you promise to eating at least 3,4 or 5 fruit or veg a day for the next week. Please text back the number of fruit you would like to commit to eating per day. The back CAMP followed by yes or no to 8810.	Hey! Are you ready to get healthy? If you haven't had time to reply to your text. Text back the number of fruits you commit to eating everyday this week. Text back CAMP followed by yes or no to 8810.	Are you managing you 5-a-day promise this week? Good luck and keep going! Text back CAMP followed by yes or no to 8810.
Remember the Fitness Cycle, "The more physical activity you do the easier it becomes and will help improve your fitness."	Can you commit to 10,000 steps on the pedometer every day this week? You can do it! Remember this summer! Text back CAMP followed by yes or no to 8810.	Hi. If you haven't replied to you commitment text do so now and get on your pedometers! Text back CAMP followed by yes or no to 8810.	Have you managed to rack up 10,000 steps on your pedometer each day this week? Let us know! Text back CAMP followed by yes or no to 8810.
Most soft drinks are high in sugar and calories – remember the "What's in my drink?" session on camp.	Can you commit to only drinking sugar free fruit squash or water each day? Text back CAMP followed by yes or no to 8810.	Thanks to you guys who texted back! Here's another chance if you didn't. Text back CAMP followed by yes or no to 8810 if you can commit to drinking sugar free squash or water this week! Txt 8810	Hey. It must be difficult to only drink sugar free drinks. Have you managed to stick to your promise? Let us know. Text back CAMP followed by yes or no to 8810.
You should try and keep snacking to a minimum.	Can you commit to only 2 healthy snacks per day this week. You can do it! Text back CAMP followed by yes or no to 8810.	So if you haven't made your commitment yet text back 'Yes or No' to eating only 2 healthy snacks per day. Txt back CAMP t0 8810 followed by your choice.	How is your commitment going? Have you managed to stick to eating two snacks in between meals each day? Text back CAMP followed by yes or no to 8810.
Eating out and take-aways have high calories.	Can you promise to not eating out or taking away food this week? Text back CAMP followed by yes or no to	If you haven't had time to promise to not eating out this week. Do it now. Text back CAMP followed by yes or no to	Have you managed to eat at home for dinner each night this week?. Text back CAMP followed by yes or no

	8810.	8810.	to 8810. Well done if you have!
Chips and fried foods are fatty and unhealthy.	Can you commit to making sandwiches for school this week. You can have more choice with sandwiches. Text back CAMP followed by yes or no to 8810.	So are you gonna eat sandwiches for lunch this week? If you haven't replied yet do it now! Text back CAMP followed by yes or no to 8810.	Making your own sandwiches gives you so much more choice. Have you made your own sandwiches this week as you promised? Text back CAMP followed by yes or no to 8810.
Deserts can be high is calories, sugars and fats.	This week can you commit to eating only fruits for desert each day. To commit to this text back CAMP followed by yes or no to 8810. You're doing really well!	Morning. If you haven't replied yes with you commitment do it now. Text back CAMP followed by yes or no to 8810.	Have you managed to eat fruits for deserts this week as you promised? Did you like this commitment Let us know. Text back CAMP followed by yes or no to 8810.

Chapter 11 Discussion

11.1 Main Findings

The study supports the use of commonly used behavioural tasks as a predictor of the difference in weight and weight reduction in three different obese population groups, seeking both surgical and non-surgical weight management. Psychometric tests were used, as in certain patient populations it has been shown to detect brain changes before MRI changes are evident (Schmand et al., 2014). The tasks were particularly discriminatory in the adolescent group with both temporal discounting and the SSRT being able to distinguish obese from non-obese participants. This discriminatory ability of the tasks to distinguish between obese and normal weight participants diminished into adulthood. Over a shorter period of time of three months, the SSRT was found to be a predictor of weight reduction in the obese adolescent group, when taking gender, the number of weeks in camp, age and change in BMI into account as co-variables. A switch from SSRT to the temporal discounting constant was noted as a predictor of weight reduction during the weight maintenance stage at 5 to 6 months. The SSRT recorded in the study groups were similar to normative data for this group, and, at present, no such data exists for the temporal discounting dataset.

When comparing the performance of both behavioural tasks commonly used personality questionnaires the SSRT was found to be associated with Novelty Seeking in the Temperament and Character Inventory and negatively correlated with lower self-control from the BIS. The SSRT metric was also correlated significantly with a large number of eating disorder questionnaires including greater restraint, greater hunger, less positive affect and generally higher global scores of the EDE questionnaire.

In addition to being able to predict weight reduction, the Stop Signal Task was found to be modifiable my modafinil neuro-cognitive enhancement agent which is thought to act through dopamine pathways in the brain. The temporal discounting task was unaffected by modafinil. The performance on both tasks were also unaffected by atomoxetine; a selective noradrenaline re-uptake inhibitor.

In order to target the impulsive behaviours commitment messages were selected as a tool to encourage weight loss maintenance in the adolescent obese group whilst in the community. Commitments were found to significantly halt weight gain in this group as part of a randomised controlled trial.

11.2 Relation to previous studies

Although the role of personality in obesity has been of interest since the late 1950's, Suczek and colleagues (1957) were first to consider whether there are common psychologic characteristics among the obese and whether there were psychological differences among the obese which related to differences in the degree of symptom and the ability to lose weight. The authors theorised that by evaluating two sets of groups of obese women, which seem to represent functional differences among the obese; firstly, the grossly obese compared to the mildly obese and, secondly, those who lose large amounts of weight in a weight reduction programme compared to those who lose relatively little. If this subset of individuals exhibited traits related to important psychological variables, it may unearth useful leads for further study and theory. This early comparison found obese women to be power oriented in their interpersonal orientation and are also more likely to be anxious, introspective neurotics.

In predicting factors related to weight reduction the authors found that those who were heaviest and had consistently high mean dominance scores lost the most pounds in 16 weeks. These findings are suggestive that there is unlikely to be a linear relationship between ability to lose weight and a single psychological characteristic. Predictors are more likely to contribute as a combination of variables related to weight loss. These may include psychological, symptomatic variation, social and intrapsychic factors. Authors also acknowledge the limited number of psychological variables tested and considers self-management of oral and other impulses and the use of regressive mechanisms, such as addiction to deal with psychological difficulties.

There is currently very little known about the predictors of weight reduction in those undergoing bariatric surgery. Evidence suggests that re-existing psychological disorders in obese individuals is a major problem especially in patients with a BMI beyond 40 kg/m2 and have tendency to persist or rebound after surgery. Elkins et al., (2005) reported that a large number of patients with a pre-operative mood disorder such as depression re-experience post-operative symptoms. The relative risk of suicide and accidents is also 1.58 times that of obese controls in patients who have had gastric by-pass surgery (Adams et al., 2007). The current data suggests as many as 60% of patients attending the Imperial Weight Management Centre suffer from either anxiety or depression. This is supported by bariatric patients with a BMI of >40 having a five fold increase in depression and Walfish and colleagues (2004) also found half of their bariatric surgery candidates had a diagnosis of depression. Therefore, it seems pertinent to screen bariatric patients pre-operatively as the assessment may determine their post-operative course.

The variation in finding from measurement of impulsivity in both the obese and normal weight groups has shown the true multifaceted nature of impulsivity. The Stop Signal Task was able to differentiate with between obese and non-obese adolescents and in the bariatric study showed the greatest number of correlations with components from dietary questionnaires. It was also able to predict short-term weight reduction at 2 months.

The temporal discounting constant was able to predict weight loss in both the adolescent and bariatric patient group, however, it did not correlate well with the Novelty Seeking component of the JTCI or any of the eating disorder questionnaires used in the bariatric study. It could mean that Temporal Discounting is an independent facet of impulsivity.

An important notice is that when analyzing the behavioural measures it may have been beneficial to take into account other confounding factors. Performance on the Stop Signal Task, for example, could be affected by intelligence whereas performance on the Temporal Discounting Task could be affected by an individual's socioeconomic status.

11.3 Strengths and Limitations

Although the study does show a strong association between impulsivity measures and weight reduction it is liable to confounding variables. The most important to note is intelligence, especially when considering performance on the temporal discounting task. There is known to be a strong correlation between childrens' ability to resist temptation in the famous marshmallow experiment (Mischel, Ebbesen & Zeiss, 1972) and a number of cognitive outcomes including SAT scores (Shoda, Miscel $ Peak, 1990), IQ (Funder & Block, 1989) and college GPA (Kirby, Winston & Santiesteban, 2005).

Moreover, while several theories regarding the maintenance of binge eating and obesity highlight the role of external-cue restraint in precipitating binge episodes, the role of emotional regulation was also recently examined. Some research has demonstrated that negative emotional states serve as triggers for the return of unhealthy eating in dieters and that eating in response to emotion increases food intake (van Strien et al., 2003).

One of the major difficulties in integrating work on adaptive and maladaptive traits is related to a fundamental limitiation of factor analysis. The limitation is that extrastatistical information is needed to specify the structure of the underlying biologic and social variability in personality traits. Factor analysis can only determine the number of dimensions, but not the underlying causal structure, location, or rotation in space. In other words, descriptive data about behaviour are not sufficient to permit any strong preference among alternative ways of summarising descriptive behavioural data. For example, Gray (1981) has used the observation about the effects of anti-anxiety drugs on personality to argue that the structure described by Eysenck does not correspond well to underlying biologic variation. For example, drugs that reduce scores on measures neurotisism, such as alcohol, barbiturates and benzodiazepines, also consistently reduce scores on measures of introversion suggesting that these dimensions share biologic determinants even though the Eysenck's model assume they are independent processes. The nature of the study design also means one cannot claim causality between impulsivity and obesity or infer the direction of the relationship. When amalgamating there is a large sample number, individual studies have a limited sample number which has implications for the generalisability of the study findings. This however is a weakness in the field as a whole. Neurocognitive testing using behavioural tasks is time consuming and is particularly difficult in the adolescent group when attempting to maintain participants concentration. The obese adolescents were matched with a cross-sectional normal weight population. Any changes due to the camp would have been convincing with the longitudinal follow-up of an obese control group not attending camp. A longer follow-up period would have been ideal as the maintenance of weight reduction at two years is less well documented and needs addressing. Particularly in bariatric surgery as it is thought weight reducation in the first two years is thoought to be anatomical in nature and less related to psyche. Validated measures of impulsvity were used in all studies, however none of these incorporated food related or eating behaviours. The reason being the findings from such tests are incocnsistent and more difficult to interpret. The other major dasadvantage of the measures deployed is that there is no direct measure of the neuronal pathways involved and any changes in the brain are hypothesis driven.

11.4 Clinical Implications

Although differences in the obesity patient group have been identified and the need for differential treatments understood (Browness & Wadden, 1992; Schwartz & Brownell, 1995), little progress has been made in matching treatment plans to individual needs. At present, the non-surgical samples investigated have used behavioural therapy. The underlying principle is based on replacing classically conditioned cues and creating new connections (Stuart, 1996). An example may be the process of connecting learned associations between food intake and a neutral stimulus such as painting. Behaviour techniques teach people to identify cues that trigger overeating and learn to modify their behaviour pattern in response to these cues. Individuals will seek positive reinforcement by replacing eating with alternative activities (Foster et al., 2005). Behavioural therapy focuses on three key features (Wadden & Foster, 2000). Firstly, the goals identified must be clear and easy to appraise (this was taken into account when designing the SMS maintenance intervention). Secondly, the intervention must be process-orientated, where participants must have insight into factors that hinder or facilitate achievement of the health goal. Finally, behavioural therapy encourages gradual and persistent changes. One of the key problems with behavioural therapy is that weight reduction often plauteaus and attrition rates can be high. In this case, impulsivity measurements pre-intervention can stratify participants entering a behavioural therapy intervention into how likely they are to lose weight so that extra support can be provided accordingly or the duration of therapy is extended in order to support behaviour change. The second method is by which serial measurements of various impulsivity traits can guide management of the patients. Farmer and Golden (2009) have listed the behavioural interventions that can be used with various functional formulations of impulsive behaviours (Table 12-1).

Table 11-1 Behavioural interventions that can be used with various functional formulations of impulsive behaviours

Functional response Domain	Primary Functional Property of Behaviours	Examples of Intervention Techniques
Excessive appetitive behaviour	Produce positive reinforcing consequences, particularly those that are socially mediated	Remove positive reinforcers associated with excessive behaviour (e.g., attention); contingency management procedures; covert sensitization; cue elimination; skill training (e.g., assertiveness)
Behaviour ineffectively controlled	Behaviour not influenced by the consequences that it produces	Skills training (e.g response reflection skills); functional/ chain analysis of behaviour; problem solving.
Experimental avoidance	Produce negative reinforcing consequences (e.g., relief from aversive private events)	Reduce/eliminate establishing operations that lead to avoidance behaviour; 'urge surfing'; exposure-based therapies; skill training.
Deficits in rule control	Non-reactivity to cues that would otherwise inhibit behaviour	Motivational interviewing; acting towards a goal; 'committed action' functional chain analyses of target behvaiours
Poor inhibitory skills	Non-reactivity to cues that would otherwise inhibit behaviour	Stimulus control techniques; cue exposure
Poor stimulus discrimination/ inappropriate stimulus control	Behaviour is inappropriate for contexts where it is displayed	Discrimination training; stimulus control techniques; mindfulness interventions; self-labeling training
Inability to cope with delay	Selection of less favourable immediate consequences rather than more favourable delayed consequences.	Contingency management: self management technique; skill training

11.4.1 Cognition and Impulsivity

More recently Benjamin and colleagues (2014) have identified a relationship between cognitive ability and 'behavioural' risk preferences. As discussed in the introduction, cognitive ability is thought to partially dependent on ones state of ego depletion (Hagger, Wood, Stiff & Chatzisarantic, 2010). Therefore, those who may have limited resources from the onset will become further depleted of cognitive resources during the weight loss intervention. Consequently, cognitive enhancement agents such as modafinil which may strengthen ones resources could play a vital role in the management of patients.

The role of cognitive enhancement may be of particular use in patients having less radical obesity surgery. Both procedures investigated as part of the thesis significantly change the anatomy of the digestive system. They also bear a high risk of severe complications which makes them unsuitable for wide scale implementation to overcome a global problem. There is an interest in the bariatric community on how to optimize minimally invasive procedures such as the laparoscopic gastric band and the endobarrier. These procedures involve minimal anatomical changes and hence a smaller weight reduction (42%) in comparison to conventional procedures (67%) during longer term follow-up (Franco, Ruiz & Gagner, 2011). To date, these relatively cheap and easy to fit devices have not been in favour with clinicians due to the high proportion of patients who regain weight and are, as a result, unsatisfied with their outcome. Therefore, an avenue for further work could involve testing the role of impulsivity in patients who undergo these procedures and look to measure changes in impulsivity with weight reduction. For example, at 10% weight loss or 15 % weight loss instead of a given time period, when weight loss can be variable. One would expect to find those who lose the least weight to remain impulsive at interval testing.

Although the SSRT was found to correlate with commonly used eating questionnaires and performance in the task was modifiable by modafinil it was in fact the Temporal Discounting Constant which was a predictor of weight reduction in both the obese adolescent group and the bariatric patient group at approximately 6 months. The performance on the Temporal Discounting Constant was also not modifiable by pharmacology. The evidence supports the conclusion that the two tasks and so explores a different facet of impulsivity. When using the Temporal Discounting Task it is important to establish whether monetary discounting actually parallels real life health choices. There is a substantial observed difference in the pattern of discount rates between monetary and health outcomes. Several studies have directly tested this, finding at best weak correlation between the two domains. Cairns (1992) compared the health-discounting task described above (using a health state described in terms of depression) with a monetary discount task. Overall, monetary discount rates were found to be significantly higher than health discount rates. Sub-samples of health discount rates were correlated with each other, as were subsamples of financial discount rates. However, there was no significant correlation between health and financial discount rates. Chapman and Elstein (1995) set out to directly compare subjective discount rates for health and money by testing for a correlation between the two domains. They included hypothetical vacations of varying duration as a third domain. In this study the health outcome was described as period of restoration to full health from a background of illness provided by one of two new treatments, with a different delay to onset and duration for each treatment. Overall, discount rates were high (geometric mean 1.12), and mean discount rates for health (geometric mean 1.24) were found to be significantly higher than those for money (geometric mean 0.99). Correlations between sets of matching questions

within a particular domain, e.g. money, were quite high (mean 0.65), demonstrating reasonable internal consistency. However, overall between domain correlations were significantly weaker (mean 0.25), suggesting that participants discounted differently depending on whether the outcome was monetary gain, improved health or a vacation. In a later confirmation of domain independence, Petry (2003) studied discount rates for hypothetical health, money and freedom (from time spent in jail), with the finding that health and freedom discount rates were correlated, but neither domain was correlated with monetary discount rates.
Strategies described to reduce impulsive decision making by straightforwardly targeting the executive system included working memory training using standardized computer tasks (Bickel, Yi et al., 2010). In individuals who were being treated for psychomotor stimulant addiction, the programme significantly reduced discount rates by an average of 50%. Yi and colleagues (2010) observed a change in smokers' discount rates as a result of contingency management intervention that reduced smoking. Finally, Black and Rosen (2011) assessed the effects of money management based substance use treatment intervention on discount rate. Adults with histories of cocaine and/ or alcohol use received outpatient psychiatric treatment and advise regarding money management as the primary intervention. It was found the intervention was associated with significantly less delay discounting and less cocaine use relative to the control group.

The ability of both behavioural tasks to differentiate between obese and normal weight adolescents, but not adults, may be due to the neural plasticity of the brain during this critical period of development. The differential development of the frontal cortex and the sub-thalamic brain structures are likely to lead to a greater variability in impulse control during this age too (Hare, Camerer, & Rangel, 2009). To support this hypothesis, many global initiatives have focused on Early Childhood Development to provide a foundation for future learning and wellbeing in children (UNICEF, Worldbank). A similar attitude may be necessary in more developed countries to help maintain a healthy weight from an early age.

11.5 Further work

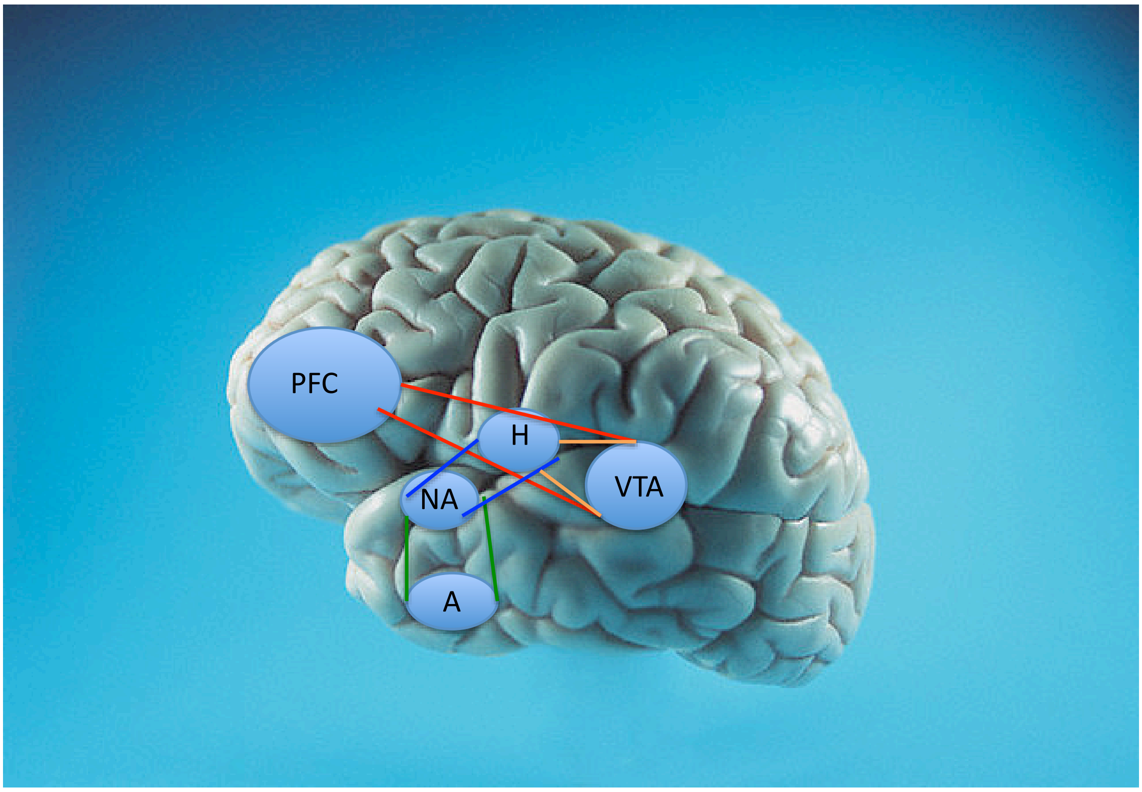
According to Cloninger (1987) and most of the personality perspectives on impulsivity, individual differences in reactivity to diverse environmental events and behavioural consequences are linked to biological predispositions. All current therapies for weight reduction have in common an isolated focus on attaining a negative energy balance by the environmental modification of conditions, with neglect of intrinsic neurobiological and psychological aspects of overeating such as hypothalamic appetite regulation, mood, stress balancing or reward perception. Therefore, unless a central change in the neurobiological mechanisms underlying obesity are understood and tackled, weight will begin to regain when the individual returns to their normal environment and nutritional habits.

The similarities in the neurobiological changes present in obesity and drug addiction have been brought to attention in the pharamaco-modulation chapter. Specifically, the reward processing in both over eating and addiction activate the mesocephalic dopaminergic pathways (Volkow & Wise, 2005). Also, similar to addictive behaviour, those who are obese often ingest more food than intended and often have difficulties participating in social occupations activities due to their condition (Barry et al., 2009). Those with a high BMI are aware of the negative consequences to their health yet they continue to overeat. In 2012, it was proposed that obesity should be considered as DSM-V criteria (Volkow & O'Brien, 2007). However, as the research focusing on the neural mechanisms is still in its infancy, the Eating Disorder Work Group decided that obesity should not be included in DSM-V (Marcus and Wildes, 2012).

The study in the adolescent group support that SSRT and temporal discounting constant may be modifiable or even potentially be trait variables making them amenable to intervention. If discount rates serve as a summary measure of decision making processes that underlie a range of impulse-control disorders, then, the potential value of altering an individual's discount rate becomes immediately apparent. As already mentioned in the Neuronal Circuitry upon which this work is based, the interconnected neuronal networks model posits that decision making reflects the relative balance three interacting biological systems. The salience network which values immediate reinforcers. By contrast, the more recently evolved default mode network and the executive control system made up of portions of the prefrontal cortex may be needed for the inhibition of the impulsive system and the associated valuation of the delayed reinforcers. The proposed theory postulates that relative activation of these two decision systems is associated with behaviour in delay discounting procedures and by extension, with clinically relevant choice scenarios such as whether to eat a tempting food. In support of this theory, interventions that are thought to strengthen inhibitory control that the executive system exerts over the impulsive system (i.e., increases neuronal firing and regional blood flow to the lateral prefrontal cortices) should be associated with an increased subjective valuation attributed to delayed rewards and resulting increased choice of delayed rewards.

The figure below (Figure 12-1) represents the Prefrontal cortex (PFC) and amygdala, brain regions that are thought to encode information related to the reward value of food (Baxter & Murray 2002; Holland and Gallagher, 2004; Kringelbach et al., 2003; O'Doherty et al., 2002; Rolls, 2010). The insula processes information related to the taste of food and its hedonic valuation (Balleine & Dickinson, 2000; Small, 2010). The Nucleus accumbens (NA) and dorsal striatum, which receive dopaminergic input from the ventral tegmental area (VTA) and substantia nigra, regulate the motivational and incentive properties of food, i.e., reward processing (Baicy e tal., 2007; Berridge, 2009; Farooqi et al., 2007; Malik et al., 2008). Abnormalities in dopamine metabolism result in a dysfunctional motivational response and an inability to cope with stress (Koob & Le Moal, 2008). The hypothalamus (H) may regulate rewarding responses to palatable food and drive food-seeking behaviours (Kelley et al., 1996). Projections to the hypothalamus from the PFC and amygdala (A) are, therefore, directly involved in food intake regulation.

Figure 11-1 Brain areas related to food intake



Functional neuroimaging would be the natural progression of the current work. Functional imaging in patients undergoing bariatric surgery is likely to yield interesting finding with regard to the interconnected neuronal networks already mentioned. Scholtz and colleagues (2013) compared the brain regions of patients who had undergone gastric bypass versus gastric banding using functional MRI. It was found that brain reward systems including the orbitofrontal cortex, amygdala, putamen, caudate and nucleus accumbens, during evaluation of the appeal high-calorie food pictures was less after gastric by-pass than after gastric banding surgery. Therefore, delineation of such pathways during the performance of psychometric tasks and a general linear model analysis to measure BOLD activation could potentially confirm active brain pathways.

Chapter 12 References

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