The Effect of Working Memory Training on Executive Function in Reduced-Obese Women: Implications for Long-term Weight Loss Maintenance (The Mind the Gap 2 Study)

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DECLARATION

I, …TRINITY DANIELLE RUDNER…, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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FOREWORD

This thesis has been written to fulfil the requirements of a Master of Medicine in Exercise Science and Sports Medicine. It is the continuation of the original study, *Mind the Gap: Brain-behaviour Barriers to Successful Weight Loss Maintenance* (Hume, 2015a), which found that women who were able to maintain their weight loss in the long term exhibited different habits, such as more disciplined eating and exercise regimes, to those that regained weight after weight loss (Hume, 2015b). Furthermore, Hume (Hume et al., 2015c) found that successful weight loss maintainers displayed greater cognitive control over their food intake, and suggested the use of cognitive remediation therapy as a means to successful long term weight maintenance. This led to the proposal for *Mind the Gap 2* with the hypothesis that improving executive function may assist in the ability to maintain disciplined habits after weight loss.

Limitations

It is important to note that this project was affected by the outbreak of Covid-19 in 2020, which resulted in the halting of all research activities. This has unfortunately resulted in a change from the original protocol, of which the biggest limitation was the lack of participants and control subjects. The original scope of the thesis was to have three groups of participants: 1) the experimental group, reduced-obese women, who took part in the intervention; and the control groups, 2) reduced-obese and 3) steady-weight women, who were not to take part in the intervention. The outbreak and subsequent extended lockdown that ensued resulted in a halt in recruitment of the two control groups and the inability to collect baseline and post-intervention data from those few who had already started the testing procedures. It is important to note that the small sample size and lack of controls are a result of this, which may have affected the scientific precision and relevant significance of the findings. Due to these limitations an additional methodological chapter was included to increase the scientific relevance of this dissertation.

Contents

ABSTRACT

Background: Weight loss often results in various physiological and behavioural compensatory changes which increase susceptibility to weight regain, resulting in unsuccessful weight-loss maintenance in the long term. Evidence suggests that working memory (WM) plays a key role in self-regulation and executive control, which is vital in overcoming these compensatory responses to weight loss. The current study therefore aimed (1) to identify the compensatory responses that occur with weight loss, (2) to investigate whether WM training (WMT) can improve executive control in reduced-obese women, and (3) compare subjective and objective WM methodologies.

Methods: Reduced-obese (n=23) and stable-weight (n=6) women were recruited in this study. All 29 women were characterised at baseline testing for various physiological, behavioural and cognitive outcomes. After baseline testing, a subset of 19 reduced-obese women underwent 6-weeks of WMT, after which they completed post-intervention testing and a 6-month follow up. The series of assessments at baseline and post intervention included: anthropometric measurements; eating and behaviour questionnaires; executive function and working memory tests; metabolic rate; blood profile (HbA1c; glucose; insulin); and appetite measures.

Results: Reduced-obese women showed signs of greater eating disordered behaviour and greater post-prandial energy efficiency compared to stable-weight women, although there appeared to be no difference in their executive function. The WMT appeared to result in improved WM capacity in reduced-obese women, which was retained in the long term, and there was some evidence of transfer to behaviour, with an observed reduction in eating-disordered behaviour. When comparing WM methodologies there appeared to be a contradictory relationship between subjective and objective WM measures.

Conclusions: The results from this study support the evidence that physiological and behavioural changes occur in those that have lost a significant amount of weight, stressing the importance of finding weight-loss therapies that target these compensatory responses to weight loss. WMT was found to improve WM capacity in reduced-obese women, however, study limitations mean that the effects the training may have had on behaviour and weight maintenance could not be accurately determined. Furthermore, the contradictory relationship found between subjective and objective measures of WM add to the uncertainty that they measure the same underlying construct, which highlights the importance of utilising various types of measures in the analysis of WM and executive function.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
AUC	Area Under the Curve
BDI	Becks Depression Inventory
bDS	Backward Digit Span
BIA	Bioelectric Impedance Analysis
BRI	Behaviour Regulation Index
BMI	Body Mass Index
BRIEF-A	Behaviour Rating Index of Executive Function – Adult version
CO_2	Carbon Dioxide
DS	Digit Span
EDE-Q	Eating Disorder Examination Questionnaire
EEQ	Emotional Eater Questionnaire
fDS	Forward Digit Span
GEC	Global Executive Composite
GPAQ	Global Physical Activity Questionnaire
HAW	Highest Adult Weight
IQR	Interquartile Range
MI	Metacognition Index
ML	Max Length
MS	Mean Span
MUD	Methamphetamine Use Disorder
O_2	Oxygen
REE	Resting Energy Expenditure
RER	Respiratory Exchange Ratio
RMR	Resting Metabolic Rate
SD	Standard Deviation
SUD	Substance Use Disorder
TE_ML	Two Error Max Length
TE_TT	Two Error Total Trials
TLM	Time since Last Meal
VAS	Visual Analog Scale
WEL	Weight Efficacy Lifestyle Questionnaire

WHtR	Waist to Height Ratio
WHO	World Health Organisation
WM	Working Memory
WMT	Working Memory Training

Chapter 1 Review of the Literature

1.1 Introduction

In 1997 the World Health Organisation (WHO) recognised obesity as a global epidemic (World Health Organization, 2000). Yet 20 years later we are still seeing an increase in excess adiposity, with more than half of adults worldwide being classified as overweight or obese. This condition is prevalent across all income groups, creating both an economic and health burden on societies. Excess adiposity leads to, and is included in, metabolic syndrome, a cluster of conditions such as high-blood pressure and high-blood glucose, which can lead to the development of non-communicable diseases (cardiovascular disease, diabetes, stroke, etc.) (Guh et al., 2009; Habib & Saha, 2010; Withrow & Alter, 2011). A reduction in excess adiposity can improve the metabolic profile thereby reducing the risk for the development of these conditions (Anderson & Konz, 2001; Forsythe et al., 2008).

Yet weight loss attempts are often unsuccessful. Research shows that only 50% of those that attempt weight loss are successful at losing a significant amount of weight (Appelhans et al., 2016). A significant amount of weight is defined as a reduction of at least 10% of their initial body weight; the 10% criterion is the point at which weight loss produces a positive impact on health by reducing the risk factors for the development of metabolic diseases (National Heart Lung and Blood Institute, 1998). Of the 50% that do manage to lose a significant amount of weight, research shows that the majority will regain between a third to half of the initial weight lost within a year, and up to three quarters of the initial weight lost within 5 years (Anderson et al., 2001; Appelhans et al., 2016). Only about 20% of those that successfully lose weight will be able to maintain at least a 10% reduction of their initial weight in the long term (Anderson et al., 2001; Wing & Phelan, 2005). It is also important to note that in these studies a contributing factor to successful weight maintenance is the amount of weight initially lost, such that those who lose >20% of their initial weight are more likely to maintain a 10% reduction in the long term. This means that even for those who are successful at losing weight, there is still a large amount of weight regain occurring. Altogether these statistics are discouraging as without successful weight-loss procedures obesity rates will continue to rise. In order to develop effective therapies to combat obesity and weight regain it is critical to understand the risk factors and behaviour patterns associated with this condition.

1.2 The Addiction Model

As to the law of thermodynamics, adiposity accumulation occurs when there is a positive energy balance; when excess calories are consumed despite energy needs being met. Although some may argue that obesity is a more complicated construct than just over-eating, evidence shows a strong correlation between global BMI growth and global calorie intake (Doytch et al., 2016). In order for the accumulation of excess adiposity to occur, as with obesity, there needs to be a consistent positive energy balance; meaning over-eating over an extended period of time. However, it is well known that the body contains an efficient homeostatic control system that utilizes neural and chemical feedback systems to control hunger and satiety (Morton et al., 2006). This means that when energy needs change, or there is a change in body fat, the brain sends the appropriate signals to adjust our behaviour to balance our energy needs. In the case of obesity, it appears the feedback system can be overridden by another system; the reward system. It is well recognised that an appetite drive in the absence of hunger, known as hedonic hunger, occurs in response to the rewarding properties of highly palatable foods. Today, processed foods are rich in various additives, sugars and hydrogenated fats, in ratios that are entirely unnatural but together provide maximum palatability and reward (Ifland et al., 2009). Importantly, sugar has consistently been identified to cause neurochemical changes in the brain that resemble that of addictive drugs (Avena et al., 2008). These rewarding properties may also be the reason why weight loss is so difficult to achieve, as certain foods activate the same neural pathways as those implicated in substance addiction.

In fact, recent evidence has revealed the many parallels that exist between obesity and substance addiction. Behaviourally, both disorders experience cravings, withdrawal and display an inability to control their actions to abstain from unwanted behaviour (uncontrolled eating or substance abuse) (Hone-Blanchet & Fecteau, 2014). Neurologically, studies have shown similarities in the brain's dopaminergic system in response to the addictive substance (García-García et al., 2014). Drugs of abuse are known to over-activate the dopamine response, although food rewards can produce a similar effect, most notably high calorie (palatable) foods (Volkow et al., 2011). As with those who relapse from addiction, weight regain usually occurs due to a lapse in the strict dietary and exercise behaviours associated with the initial weight loss. Those who regain weight usually report a significant drop in their physical activity, an increase in fat consumption, and a decrease in their dietary restraint (Wing & Phelan, 2005). Another important neurological finding is that both conditions exhibit similar cognitive and executive function irregularities; with greater likelihood of impairment in these processes found in individuals suffering from substance addiction (Potvin et al., 2014, 2018; Simon et al., 2000; Verdejo-García et al., 2006) and individuals suffering from obesity (Fitzpatrick et al., 2013;

Gunstad et al., 2007; Yang et al., 2018). This is a promising discovery as executive function is the cognitive process that allows for the ability to control one's behaviour to achieve a specific goal. Thus, weight management through dietary control and adherence to exercise regimes may rely on executive function. Executive function may therefore be a promising insight into not only the cause for weight relapse, but also why weight gain occurs in the first place.

1.3 Executive Function and Working Memory

Dual process theory suggests that human behaviour is determined by the interaction between two competing cognitive systems: the executive (reflective) system, responsible for controlled and deliberate behaviour, and the impulsive system, responsible for automatic and impulsive behaviour (Hofmann et al., 2009). Although these two systems complement one another, under default circumstances the executive system has good control over the impulsive system, resulting in regulated behaviour in accordance with your standards and goals. In simpler terms, executive function is the process that allows you to think before you act (Diamond, 2013). When executive function is impaired the impulsive system shows greater influence, resulting in more impulsive behaviour. Executive function is often impaired in many mental disorders that are characterized by this impulsive behaviour such as attention deficit hyperactivity (ADHD) (Willcutt et al., 2005), addiction (Gould, 2010) and depression (Snyder, 2013).

Executive function is characterized by the ability of three core components: (1) inhibitory control: the inhibition of automatic impulses; (2) cognitive flexibility: the ability to shift between tasks or mental states; and (3) working memory: the retention and processing of short-term information (Diamond, 2013; Miyake et al., 2000). These cognitive processes work together to enable goal-directed behaviour. Although distinguishable, the three components of executive function share common underlying mechanisms, suggesting a correlated construct (Diamond, 2013; Miyake et al., 2000). If one component is strengthened it can build up the other two components, and the executive function as a whole will be strengthened.

It has been suggested that working memory (WM) is the largest and most vital component of executive function and that it's mechanisms underly the other two components (Hofmann et al., 2012). While WM describes the process, WM capacity describes the working memory abilities at the individual level, such that some may have a high WM capacity and some may have a low WM capacity. As WM makes up such a large component of executive function, WM capacity can be measured as a proxy for executive function; those with low WM capacity are found to have lower executive function and vice versa (McCabe et al., 2010). Research therefore shows that WM contributes greatly to many aspects

of self-regulation, including regulation of eating behaviour and emotions (Dohle et al., 2018; Hofmann et al., 2012; Houben et al., 2016; Schmeichel & Demaree, 2010).

1.4 The Role of Executive Function in Weight Management

1.4.1 Executive Function in Weight Gain

In a normal, healthy individual, diet will reflect the balance between the executive and impulsive system. The executive system advocates for what the individual understands is fundamental to the diet, such as including vegetables, fibre and lean meats. The impulsive system will advocate for palatability, such as 'junk food' or desserts. Under default circumstances, in which executive function is normal, eating habits will reflect one's conscious standards, even if it means denying the impulsive system.

For many individuals excessive weight gain occurs when there is an imbalance, resulting in the overconsumption of highly palatable and high-calorie foods. This drive to overconsume once calorie needs have been met can often be attributed to the rewarding properties of these foods. Addictive substances as well as natural rewards, such as food, cause the release of dopamine (Cami & Farre, 2003). This reward activation in response to food sensitizes the impulsive system to the substance stimuli, so that the substance becomes an automatic response. If executive function is weak the impulsive system takes control over behaviour and eating habits reflect that of the automatic response. The inability then to abstain from these types of foods can be identified as a kind of addiction, which is driven by these rewarding effects.

The executive system can be weakened through various factors or conditions allowing for the impulsive system to take control (Hofmann et al., 2009). Factors that may compromise the executive system include alcohol consumption, ego depletion, genetics and cognitive overload (Hofmann et al., 2009). For example, Friese and colleagues (2008) showed that when participants experienced an increase in cognitive load, their behaviour was more strongly driven by impulsive processes. When the cognitive system is depleted through stress or overload, the impulsive system takes control, resulting in behaviour that favours the automatic response, such as choosing highly palatable foods over healthier options. Over time, repeated repression weakens the executive system and strengthens the impulsive system, resulting in a more long-term shift in control.

The deterioration of these complementary systems is what results in impaired executive function, which has been shown to increase the likelihood of weight gain in the long term; especially when there is a strong implicit preference for highly palatable foods (Nederkoorn et al., 2010). This explains why

increased adiposity is associated with cognitive deficits, particularly executive function, across all ages (Calvo et al., 2014; Cserjési et al., 2009; Emery & Levine, 2017; Fitzpatrick et al., 2013; Rochette et al., 2016; Smith et al., 2011; Yang et al., 2018). This impaired executive function results in increased adiposity as it is associated with obesity-related behaviours, such as lower intake of fruit and vegetables (Allom & Mullan, 2014; Wyckoff et al., 2017), higher intake of fatty foods (Allom & Mullan, 2014; Hall, 2012; Hofmann et al., 2008), uncontrolled eating (Calvo et al., 2014), lower physical activity (Daly et al., 2015; Hall et al., 2008a), poor adherence to diets (Hall et al., 2008b) and a strong automatic positive attitude towards food (Hofmann et al., 2008). These are all behaviours that visibly favour the impulsive response and display a lack of discipline over diet.

1.4.2 Executive Function in Weight Loss

Just as executive function plays a part in weight gain, it also plays a part in the ability to lose and maintain weight. Food acts as a natural reward, with highly palatable foods eliciting greater reward; this means that abstaining from highly palatable food requires a great amount of self-control and dietary restraint. This is especially true when limiting food intake as evidence shows that restricting energy intake further increases the sensitivity of the food-reward circuits by stimulating the perception of reward (Morton et al., 2006). Meule (2016) found that in general current dieters performed more poorly on a WM task involving food cues compared to non-dieters, despite the two groups having similar WM capacity. During the food cue WM task the current dieters had slower reaction times and also experienced greater food cravings after the completion of the task compared to when they completed the same task using neutral images. However, dieting status was further a predictor of task performance, such that those dieters who were considered successful dieters were less likely to make errors during the food cue WM task than unsuccessful dieters. Executive function therefore plays an important role in dietary restraint and the ability to resist cravings. For example, the study by Hege and colleagues (2013) measured the WM capacity of 33 overweight and obese participants at the start of a 6 month weight-loss intervention. The authors found that those with higher WM capacity at baseline exhibited higher cognitive restraint over their food intake during the intervention and as a result lost more weight at the end of the intervention period. This is a similar finding to that of Dassen and colleagues (2018), who found that baseline WM was the strongest predictor of change in BMI following a weight loss program. Therefore, executive function is an important component when trying to limit food intake in order to lose weight, with greater executive function corresponding with greater likelihood of short-term weight loss. The lack of a long-term follow up in these studies, however, leaves a gap in our understanding of how the ability to restrict early on in the weight loss process may change in the long term. Future research would benefit

observing how executive function may change before, during and after weight loss, and in the long-term weight-maintenance period.

1.4.3 Executive Function in Weight Maintenance

Executive function may then play an even larger role in the ability to maintain weight after weight loss. This is because the weight-loss maintenance period requires more discipline and cognitive effort than the time during weight loss itself. Executive function plays an important role in maintaining discipline once motivation has diminished. During weight loss the positive benefits that are accompanied by the weight loss (such as visible changes) outweigh the perceived cost of adherence (the physical and cognitive effort taken to lose weight). When weight loss is achieved and the maintenance phase starts, the cost of adherence to physical regimes and diet begin to outweigh the benefits as there is no longer sustained positive feedback (MacLean et al., 2015). This change in motivation can be observed in the weight-loss statistics, as half of people who attempt weight loss are able to lose a significant amount of weight, however only 20% of these individuals are able to then maintain this weight loss in the long term (once the positive reinforcement of weight loss is removed) (Anderson et al., 2001; Wing & Phelan, 2005).

Executive function also plays an important role in combatting the behavioural and physiological compensatory responses that occur as a result of weight loss. When a significant amount of weight loss occurs, the body activates physiological responses in order to restore 'balance' (MacLean et al., 2015). These physiological factors include the lowering of energy expenditure in response to weight loss (reduced resting metabolic rate; increased metabolic efficiency; reduced thematic effect of feeding) and an increase in appetite (increase in appetite-stimulating hormones; reduction in satiety hormones)(Melby et al., 2017). This discordance between appetite and energy expenditure leads to behaviours that encourage weight gain such as reduced activity and a preference for palatable (high calorie) foods (MacLean et al., 2015). The discordance between these physiological factors occur as an immediate response to significant weight loss, which is why most individuals who regain weight will do so in the first year after weight loss (Melby et al., 2017). However, if weight loss is maintained after a year the chances of long-term success is increased. This is because over time appetite and energy expenditure equalize as the body adapts to the reduced body mass. In the period immediately post weight loss, the physiological drive to regain lost weight can be counteracted through behavioural intervention. Behaviours such as resisting addictive high calorie foods, not giving into immediate gratification and not succumbing to old eating habits. This behavioural modification requires a large amount of sustained discipline and self-control, both characteristics of higher executive functioning.

Research indicates that successful weight-loss maintenance occurs in individuals who adopt habits reflective of higher executive functioning; such as restricting calorie intake, weighing themselves more often and adhering to exercise regimes (Reyes et al., 2012). In comparison, those with lower executive functioning will give in to temptation and revert back to the habits that caused them originally to gain weight.

1.4.4 The Bidirectional Relationship between Weight Loss and Executive Function

Weight loss itself requires utilization of the executive system through dietary control and adherence to exercise regimes. It therefore stands to reason that weight-loss efforts could help strengthen the executive system through its engagement and the repression of the impulsive system, and thereby improved executive function further improves eating behaviour resulting in a positive feedback loop (Allan et al., 2016). However, evidence in this regard remains controversial (Favieri et al., 2019).

There have been a number of studies that have found a significant and positive association between weight loss and executive function (Brinkworth et al., 2009; Bryan & Tiggemann, 2001; Green et al., 2005; Halyburton et al., 2007; Siervo et al., 2012), although time-frame appears to be important in these studies. Studies using shorter weight-loss interventions and therefore earlier follow-ups, such as at 2 to 3 months, have found small improvements on some executive function tasks, but not others (Bryan & Tiggemann, 2001; Green et al., 2005; Halyburton et al., 2007; Leclerc et al., 2020). Those with longer interventions and longer follow-ups, such as between 4 to 12 months, seem to yield more significant results (Brinkworth et al., 2009; Siervo et al., 2012). This would imply that weight-loss efforts can gradually improve executive function over time, with greater improvements seen during prolonged adherence. Although Leclerc and colleagues (2020) would suggest it is the reduction in energy intake itself that results in improved executive function, not the act of restriction itself.

There are findings however, that suggest weight loss has no effect on executive function (Cheatham et al., 2009; Espeland et al., 2014; Martin et al., 2007). It has even been suggested that weight loss itself can negatively impact executive function (Clarkson et al., 2011; Green et al., 1997; Hester & Garavan, 2005; Kemps et al., 2005; Kemps & Tiggemann, 2005), the idea being that restrictive eating and daily self-monitoring cause cognitive overload and thereby cognitive strain, as mental resources are allocated towards these dieting behaviours (Kemps et al., 2005; Leclerc et al., 2020). For instance Meule (2016) found that in a group of women who had performed similarly on a neutral WM task, when the task incorporated food related cues the current dieters in the group performed more poorly than non-dieters. The current dieters showed slower reaction times and experienced greater post-task cravings. This idea builds on the theory that by restricting food the impulsive system becomes

sensitised to palatable foods and when confronted by these images the impulsive system tries to overcome the executive system. This could add to our understanding of why weight-loss relapse is so common.

While the literature on the effects of weight loss on executive function remain controversial, weight loss through bariatric surgery has been shown to improve neurocognitive outcomes both short term and in the long term. This may serve to corroborate the effect of reduced adiposity on executive function without the confounding influence of the psychological and mental exertion experienced during weight loss through conventional means (Gettens & Gorin, 2017).

1.5 Working Memory Training

WM is the largest component of executive function and represents the 'updating' component. It is the ability temporarily to store, analyse and manipulate short-term information; though it is distinct from short-term memory. Short-term memory is the ability to store short-term information, while WM is the ability to both store, update and process short-term information. Studies suggest WM capacity displays plasticity and can be improved through adaptive training (Klingberg, 2010). It is therefore theorized that if WM capacity can be improved through training, this in turn can improve the executive system as a whole. Thus, WM training (WMT) could be used as a remediating treatment for individuals suffering from conditions exacerbated by an impaired executive system, such as those struggling with weight maintenance or addiction.

Yet the efficacy of WMT has yet to be established, as evidence of the ability of WMT to transfer to behaviour has been inconclusive. Previous studies have consistently found WMT to produce near transfer to WM capacity in various healthy populations (Klingberg, 2010; Melby-Lervåg & Hulme, 2013). However, there is contrasting evidence in regard to the ability of WM to transfer to other areas of cognition. Some have found WMT to transfer to various cognitive functions such as attention, fluid intelligence and cognitive control (Jaeggi et al., 2008; Klingberg, 2010; Morrison & Chein, 2011; Spencer-Smith & Klingberg, 2015); while others found little evidence of transfer to these areas, with no evidence of transfer to other areas of cognitive function (Melby-Lervåg & Hulme, 2013; Shipstead et al., 2012). WMT has been used in various populations, notably substance addition, however few studies have used it for weight management purposes. For this reason its use in substance addiction may add insight into its effectiveness in impulse driven behaviours.

1.5.1 WMT in Substance-Use Disorders

Studies looking at WMT in substance addiction may add to our knowledge of the effectiveness of WMT in controlling reward-driven behaviour. Studies have found many people with substance addiction suffer from mild to severe executive dysfunction (Bickel et al., 2014; Ersche et al., 2006; Manning et al., 2017; Verdejo-García et al., 2006). These deficits appear to be present regardless of the main drug of choice, with WM deficits having been observed across various substance addictions, including alcohol (Stavro et al., 2013), methamphetamine (Potvin et al., 2018), cocaine (Jovanovski et al., 2005), and opioid addiction (Fernández-Serrano et al., 2010; Yan et al., 2014). These cognitive deficits form in the same way to that seen in obesity. The impulsive system becomes sensitized to stimuli and habits relating to the addictive substance; and the executive system is weakened and unable to inhibit this impulsive and automatic response to the substance (Verdejo-Garcia, 2016). In this way the immediate gratification of the substance takes preference over the potential future benefits of not taking the substance (MacKillop et al., 2011). There have been a number of studies that have therefore looked at using WMT as a means to enhance addiction treatment efforts through strengthening the executive system.

As in studies in healthy populations, WMT has been shown to improve WM capacity across a wide range of addictions (Gunn et al., 2018; Houben et al., 2011; Khemiri et al., 2019; Snider et al., 2018; Zhu et al., 2018). Yet its effects on substance use remains unclear. Houben and colleagues (2011) was one of the first studies to monitor the effects of WMT on alcohol consumption. They found 25 sessions of WMT appeared to reduce alcohol intake in problem drinkers. They also found that these training effects on alcohol consumption were moderated by the individuals' level of automatic preference for alcohol; those with a strong automatic preference benefitted the most from the training. Importantly, these benefits were also still present after one month. Khemiri and colleagues (2019) also focused on alcohol-use disorder, however they were unable to find any transfer effects of the training to other cognitive tasks. This may explain why they did not find a significant difference between the groups in the number of drinking occasions; however, they did observe a trend towards a reduced number of drinks per drinking occasion.

It is likely that WM improvement could reduce the likelihood of an addiction relapse. For example in other areas of SUD, Brooks and colleagues (2017) found that 20 sessions of WMT in methamphetamine-use disorder (MUD), patients improved on their self-reported feelings of impulsivity and self-regulation. Zhu and colleagues (2018) also found evidence for improved WM capacity and impulse control in MUD patients, as well as transfer effects to other domains of cognitive function. Both these papers hint that the chance of relapse is reduced as a result of the WM

improvements; however, no long-term measures were taken to indicate future abstinence. Rass and colleagues (2015) found that controls who did not take part in WMT during treatment showed an increase in opioid use. Compared to these controls, opioid use remained consistent between baseline and follow up in addicts that completed a WMT intervention. This suggests that the WMT was able to help addicts to maintain and better control their urges.

In comparison with these findings, not all studies have found positive effects of WMT in those suffering from substance addiction. Hendershot and colleagues (2018) and Wanmaker and colleagues (2018) were unable to find any improvement in WM capacity after ± 25 sessions of WMT. In addition, both of these studies as well as that of Snider and colleagues (2018) were unable to find any effect on substance use. Snider and colleagues (2018) did find that in alcohol-dependent drinkers the improvement in WM tasks was rate dependent, those with lower baseline scores improved more than those that had initially high scores. This finding is opposite to that of Gunn and colleagues (2018) who found that WMT was more effective in those that showed higher cognitive abilities at baseline. These contradictory findings could be explained by the severity of alcohol use in the participants, that there may be a threshold in which WMT can improve upon WM capacity. For instance, Verdejo-García & Pérez-García (2007) found that cocaine users showed greater impairment than heroin users on different measures of executive function, and furthermore, that severity of drug use was also associated with greater and more widespread impairment of executive components. This may be the case in two such studies that used inpatient subjects suffering from a variety of substance-use disorders (SUD). Hendershot and colleagues (2018) and Wanmaker and colleagues (2018) were both unable to find any effects of WMT on WM capacity or substance use. As their patients suffered from varied SUDs and were in a rehabilitation centre, it is possible their addiction was too severe to benefit from any kind of training. Without improved WM capacity, one would not expect any changes to be observed in substance use. With this in mind, WMT may not be of benefit in cases of severe addiction as there is a reduction in WM functioning; however, in those with only slight or moderate executive dysfunction it is possible that they may obtain more benefit from training. Altogether the results of these studies are positive and indicate WMT may be of benefit in controlling addictive behaviour.

1.6 Working Memory Training for Weight Management

Although WMT has been studied as an adjunct treatment for a variety of disorders, including SUD, little research has been conducted using it as an aid in weight management.

1.6.1 WMT in Weight Loss

To date only three studies have studied the effect of WMT on weight loss through dietary control. These studies found promising results after only 20-25 sessions of WMT, suggesting WMT can help to facilitate improved food choices and intake. The study by Houben and colleagues (2016) examined whether WMT would improve on dietary self-regulation in overweight participants. They found that in those who completed training there was an overall reduction in psychopathological eating-related thoughts as well as reduction in emotional eating. Overall food intake, however, was reduced only in participants who scored high on dietary restraint; in other words, participants who had increased intentions to restrict their food intake. The study by Whitelock and colleagues (2018) had similar findings. The study aimed to use WMT as an aid to improve dietary control in type 2 diabetics, they found WMT appeared only to facilitate reduced fat intake in those who were already highly motivated to do so. This would suggest that WMT alone may not be able to support weight loss without the presence of motivation and knowledge on how to achieve it. Working on this theory, the study by Dassen and colleagues (2018) recruited only overweight and obese participants who exhibited a strong desire to lose weight, into a WMT intervention. They also included an educational intervention to provide them with knowledge on healthy lifestyle changes to encourage weight loss. The study found that those who completed the training in conjunction with the education intervention consumed significantly less calories in the post-intervention test compared to controls who completed only the educational intervention. However, there was no difference in change in BMI between the groups and no evidence of transfer effects of the WMT to feelings of self-control or eating disorder pathology. In terms of the lack of BMI change, especially considering there was a change in calorie consumption, authors suggested this may be due to the short time between baseline and post testing. As a means to lose weight it appears WMT can be a beneficial addition to any weight loss intervention, yet by itself may not have the ability to aid in weight loss.

1.6.2 WMT in Weight Maintenance

It is suggested that executive function may play a greater role in weight loss maintenance than in the actual weight loss itself (MacLean et al., 2015). WMT then might be of more benefit in ensuring long-term weight-loss maintenance. This is because weight-loss maintenance requires more discipline and cognitive effort than during the actual weight loss itself, as mentioned previously. Therefore, WMT may help in maintaining dietary discipline and adherence to physical activity once the goal of weight loss has been achieved.

Another reason that WMT may be of more benefit for weight-loss maintenance is that there already needs to be a level of executive functioning in order to lose weight in the first place (Hege et al., 2013). Studies have found that those with severe executive function deficits may not benefit from WMT, as the deficit may be too great to improve upon, whereas those with only slight or moderate executive deficits may show greater benefit from training (Gunn et al., 2018; Khemiri et al., 2019).

Only one study to date has looked at WMT as an aid in weight loss maintenance. The study by Verbeken and colleagues (2013) studied forty-four overweight and obese children who took part in a weight-loss intervention. In the last 2 months of the 10-month weight-loss intervention, twenty-two of these children completed 6 weeks of executive function training, of which each session was made up of both a WM task and inhibition task. They found that those who completed the training not only improved in their overall executive functioning, but also exhibited better weight maintenance at their 8 week post-intervention follow up, compared to the children who did not take part in the training. However, these weight maintenance effects had already begun to diminish by the 12 week follow up. This loss in training-related gains may indicate a regression in WM capacity, suggesting that WM needs regular booster training in order to be maintained. As this study examined children, future studies should therefore focus on these effects in adults and look at the effects of "maintenance" training sessions to see if they improve on long-term follow up.

1.7 Conclusion

It is clear from the literature that executive function plays an important role in weight management, not only in weight gain or loss, but also in weight maintenance, making it a vital role in obesity management. If executive function can be improved through WMT it may be the key to successful long-term weight loss maintenance. Research shows that WMT results in improvements in WM capacity for many individuals, including those suffering from addiction. However, there is inconclusive evidence as to whether or not this improvement is able to directly transfer to the executive function as a whole and further transfer towards a change in behaviour. Of the few studies that have looked at the effect of WMT in reward-driven behaviours, improvement in WM capacity has subsequently led to improvement in behaviours such as a decrease in food intake (Dassen et al., 2018; Houben et al., 2016), better mood and feelings of self-regulation (Brooks et al., 2017), and better control over drinking behaviour and substance use (Brooks et al., 2017; Houben et al., 2011; Khemiri et al., 2019). Though it's important to note that these effects are more prominent in those who want to actively change their behaviour and depend on a certain level of executive functioning. In terms of weight management WMT appears to help control eating behaviour when there is a strong motivation to do

so, which is why it may be more effective in weight-loss maintenance. Yet, there is still very little research is this area, and controversy still exists around how executive function and WM change with weight loss and whether these effects remain present in the long term.

1.8 Aims and Objectives

As there is little research in the area of WMT for weight management, this study aimed to add to this field of knowledge by observing the effects of a 6-week WMT on a group of reduced-obese women.

Chapter 1: Experimental Aim

The secondary aim of this study was to describe any behavioural, physiological and cognitive differences that may exist between reduced-obese women and stable-weight women. An important objective in this was to focus on whether time since weight loss had any effect on these differences that may exist.

Chapter 2: Experimental Aim

The primary aim of this study was to observe the effects of a WMT intervention on significantly reduced-obese women, the objective being to determine whether the WMT intervention improved WM capacity, and if this in turn had an effect on various physiological and behavioural outcomes associated with weight loss maintenance.

Chapter 3: Experimental Aim

An additional secondary aim of this study was to explore the associations between the different types of measures used to measure executive function. The objective was to determine whether subjective and performance-based measures of executive function displayed a relationship.

Chapter 2 Methods

2.1 Participants

Participants (n=29) were recruited through various means of advertisement including social media, weight-loss groups, radio, and word of mouth. Participants were recruited under two conditions: reduced-obese women (RED, n=23) and stable weight controls (Stable, n=6). Criteria for the reduced-obese condition included women between the ages of 25 and 45 years who had recently achieved significant weight loss through conventional means. 'Recent' was defined as having reached their goal weight within the past 18 months. The participants needed to have been classified within the obese range before weight loss (BMI >30 kg/m^2), and having then reduced their obesity status (BMI < 32 kg/m^2) through 'significant weight loss', which was defined as a minimum of a 10% reduction in body weight. The RED condition was further divided into: recently reduced-obese (RED-R), those who had lost 10% of their body weight within the 6 months prior to testing; and stable reduced-obese (RED-S), those that had remained weight stable within the 6 months prior to testing (having lost 10% within the 6-18 months prior to testing). Stable weight controls (n=6) were recruited as a control group and were age-and-BMI-matched to the experimental condition (i.e. BMI < 32 kg/m^2; age 25-45 years). Criteria for stable weight controls included women with no significant weight-loss history and no weight fluctuations >3kg over the past 3 years. Exclusion criteria included any hormonal or chronic condition affecting energy expenditure, which included pregnancy or current lactation. Of the reduced-obese women, those recruited within the first year of the study (n=19) were selected to complete the full experimental procedures involving the WMT intervention. The following year, the reduced-obese control group were age-and-BMI-matched to the experimental group.

2.2 Experimental Design

Screening

Prior to baseline testing, participants were telephonically questioned on their weight history as well as briefed on the testing procedures. Participants were then sent a link to a series of online questionnaires to complete the screening process. Medical history and reproductive-health questionnaires were completed to exclude any participants who were on any chronic medication or suffered from any conditions that might affect energy expenditure. A dieting and weight-loss history questionnaire was completed to confirm participants were eligible for the study, and to exclude those

who did not meet the criteria. In addition, participants completed questionnaires addressing demographics, education levels, socio-economic status and employment (See appendix 2, 3, 4, 5, 6, 7).

Testing Procedure

All measures were conducted by a single researcher (TR); except in the instance of the blood-draw during Visit 2, in which a researcher, trained in phlebotomy, assisted. The main experimental procedure ran over a period of approximately 12 weeks, and consisted of 3 baseline testing sessions, a 6-week intervention period and 2 post-test testing sessions (see Fig 2.1). Participants were then invited for a single follow-up visit, Visit 6, six months after the intervention (see table 2.1 for measures taken at each visit).

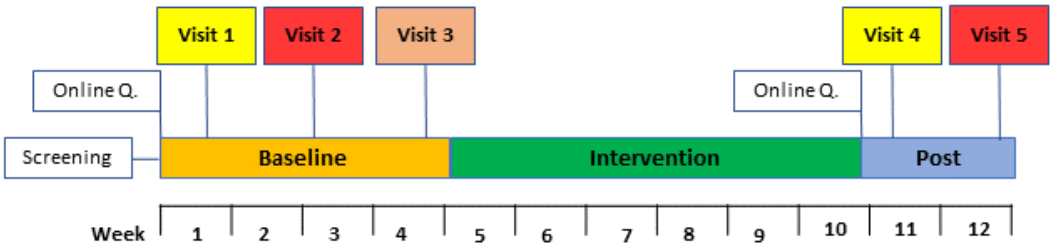


Figure 2.1: Timeline of experimental procedures over the 12 week experimental time-frame

Baseline testing consisted of the completion of online self-reported questionnaires in week 1 (BRIEF-A; WEL; Self-Efficacy; BDI) , followed by three laboratory visits spread out between weeks 2-4. Visit 1 was scheduled for any time of the day that was convenient for the participant. During Visit 1 participants were once again briefed on the full experimental procedure, anthropometric measures were then taken and participants completed two questionnaires (GPAQ; EDE-Q) and the working memory tests (Computerized n-back; DS).

Visit 2 was scheduled for week 3. For Visit 2 participants were asked to fast from the evening before, only being allowed to drink water in the morning before the visit. Visit 2 was scheduled to start early morning between the hours of 6:30 – 8am. On arrival participants were asked to lie down on a bed in order to take BIA measures followed by fasting metabolic and blood measures. Participants then completed an appetite measure form before the ingesting of a meal. Thereafter appetite measures, metabolic measures, blood measures and questionnaires (EEQ; Self-control Scale) were completed over the course of three hours.

Visit 3 was scheduled for week 4. Participants were asked to eat two hours prior to Visit 3, but not within those two hours. During this visit participants completed the subliminal images n-back task while in a fMRI scanner. The fMRI was conducted to determine the participants brain response to food cues, and how it differed to neutral cues. The fMRI imaging data was beyond the scope of this thesis and will be reported elsewhere.

After baseline testing a selected few of the reduced-obese participants (n=19) took part in the 6-week intervention period which ran from week 5-10 followed by post-intervention Visit 4 and Visit 5. Prior to the post-intervention testing participants completed four online questionnaires (BRIEF-A; BDI; Self-efficacy; WEL). Visit 4 was completed in week 11 and was a repeat of the Visit 1 measures. Visit 5 was completed in week 12 and was a repeat of the Visit 2 measures.

Long-term follow-up involved a follow-up visit at 6 months post-testing (week 38). Prior to the follow-up participants completed four online questionnaires (BRIEF-A; BDI; Self-efficacy; WEL). The follow-up visit, Visit 6, was a combination of a selected few measured from Visit 1 and Visit 2. Participants arrived fasted between 6:30-8am. During the visit the following data was collected: fasting RMR; BIA; body measurements; GPAQ; EEQ; self-control scale; and working memory tests (computerized n-back; DS).

All the laboratory visits were conducted at the Division of Exercise Science and Sports Medicine, Sports Science Institute of South Africa, Newlands, South Africa, with the exception of Visit 3 which was conducted at Groot-Schuur Hospital, Observatory, Cape Town.

Ethics

The study protocol was approved by the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (HREC REF: 230/2018) (Appendix 1). All participants were briefed on the full experimental procedures before providing written informed consent. They were made aware they could leave the study at any point and without any explanation if they so wished.

2.3 Detailed Experimental Measures

2.3.1 Anthropometric Measures

All participants were characterized for height (cm), weight (kg) and waist circumference (cm), namely, the smallest girth between the iliac crest landmark and the 10th rib. Measurements were taken after the removal of excess clothing. Height and weight were used to calculate body mass index (BMI) (kg/m^2). Waist and height were used to calculate the waist to height ratio (WHtR). Body-circumference measurements were repeated until two measurements were attained that were no more than 0.5cm

apart, with the average of those two measures noted as the final measure. Body composition was assessed using bioelectrical impedance analysis (BIA). BIA involves placing two electrodes each on the dorsal side of the right hand and the right foot; the electrodes are then connected by a single-frequency instrument to measure the resistance of a mild current through the body tissue. In preparation, participants were fasted and asked to remove all jewellery as well as void their bladder prior to the measure. The skin was cleaned with an alcohol swab before each electrode was placed. Using the equation by Sun and colleagues (2003), resistance was used to calculate total body-water (TBW/kg), fat-free mass (FFM/kg) and body fat (BF/kg), of which body fat was then used to calculate percentage body fat (BF%). BIA is a reliable and valid method to determine body composition (Savastano et al., 2010).

2.3.2 Questionnaires

SF36 Health Survey (Appendix 6) - The SF36 is a 36-item validated questionnaire that evaluates physical health and mental health (McHorney et al., 1994; Ware et al., 1993). This questionnaire was used to assess the health of participants at screening.

Generalized Self-Efficacy Scale (Appendix 9)- The Self-Efficacy Scale is a 10-item self-reported and validated questionnaire to assess perceived general self-efficacy (Schwarzer & Jerusalem, 1995; Sherer et al., 1982). Total scores range between 10-40, with higher scores indicating a greater sense of self-efficacy.

Weight-Efficacy Life-Style Questionnaire (WEL) (Appendix 10)- The WEL is a 20-item validated questionnaire aimed at overweight/obese individuals to measure judgements about their own eating behaviours (Ames et al., 2015; Clark et al., 1991). Scores range between 1-10, high scores indicate higher self-efficacy, which may be indicative of likelihood for better weight management and weight loss motivation. Lower scores indicate lower self-efficacy, which may be indicative of unhealthy eating behaviours such as binge eating, night-time eating and food addiction.

The Beck Depression Inventory II (BDI) (Appendix 11)- The BDI is a 21-item validated questionnaire that asses an individual's depression state (Beck et al., 1996; Storch et al., 2004). Using the 'American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders Fourth Edition,' it assess the severity of symptoms related to depression. The questionnaire produces a score out of 63. Lower scores (<19) indicate minimal or mild symptoms of depression, while higher scores (>29) indicate severe depression.

Self-Control Scale (Appendix 12)– The Self-control scale is a 10-item questionnaire to assess an individual's self-control (Tangney et al., 2004). Lower scores indicate a lack of self-control while higher scores indicate that an individual is extremely self-controlled.

Emotional Eater Questionnaire (EEQ) (Appendix 13)- The EEQ is a 10-item validated questionnaire used to assess the relationship between an individual's food intake and emotions (Garaulet et al., 2012). This questionnaire is specifically designed to target obese individuals. Lower scores (<5) indicate healthier eating behaviour, while higher scores (≥11) indicate the presence of emotional eating behaviour.

Eating Disorder Examination Questionnaire (EDE-Q) (Appendix 14)- The EDE-Q is a 28-item self-reported and validated questionnaire that assesses eating-disorder pathology by determining the frequency and severity of behaviours related to eating disorders (Fairburn et al., 1993; Mond et al., 2004). Questions refer to the previous 28 days and are rated on a 7-point Likert scale ranging from (0)-'no days' to (6)-'everyday'. Scores are allocated to four subscales: restraint, eating concern, shape concern, and weight concern, which together provide a Global Score. Higher scores are indicative of greater eating-disorder pathology. Original recommendations put a threshold of ≥4 for presence of eating disorder. However, recent evidence from clinical settings have shown that half of their clinical patients with eating disorders scored under 4, indicating that the threshold be lowered to ≥ 2.5 within normal samples and 3 ≥ within obese samples (Mond et al., 2004; Rø et al., 2015).

Global Physical Activity Questionnaire (GPAQ) (Appendix 15)– The GPAQ is a 16-item self-reported and validated daily physical activity questionnaire (Armstrong & Bull, 2006; Bull et al., 2009; Trinh et al., 2009). The questionnaire addresses specific activity (min) per week, for specific domains in which physical activity can be performed. The activity distinguishes between type of activity, with the two types being moderate and vigorous activity. The domains distinguish between settings for activity, with the three domains being work, transport and recreation. In addition, it also takes into account average time spent per day in sedentary behaviour.

2.3.3 Energy Metabolism and Appetite

Resting Metabolic Rate

For the metabolic measurements participants arrived in the early morning (between 6am-8am) after a minimum of a 10 hr overnight fast. Their fast time was noted as 'time since last meal' (TLM), i.e. the hours between the time of their last meal the night before to the time of the fasting metabolic measurement. Metabolic measures were taken using the ventilated hood technique (Cosmed Quark CPET). Before each visit, equipment was calibrated using a 3L syringe and the analysers were

calibrated using room air (21% O_2; 4% CO_2) and standard gas mixture (16% O_2; 5% CO_2). In addition, alcohol burns (5ml ethanol) were run frequently to monitor the accuracy and precision of the Cosmed CPET system. The Cosmed calorimeter is a validated system for measuring energy expenditure and the thermic effect of food in healthy adults (Blond et al., 2011; Vandarakis et al., 2013).

During RMR measurements participants rested on a bed in the supine position in a temperature controlled room (±23^{o}C). Fasted RMR was measured over a period of 30 min, while post-prandial RMR was measured over a period of 20 min. Post-prandial RMR was taken at 30 min, 60 min, 120 min and 180 min after meal consumption (Fig 2.2). The first 10 min and last 1 min of data collection from each measurement was discarded to account for ventilation adjustments and error. Thereafter the last 10 min of data of each collection was used to estimate resting energy expenditure (REE). Energy expenditure (EE) was calculated using instrument software according to the Weir equation (Weir, 1949). In addition the respiratory exchange ratio (RER) was continuously sampled during the measures to estimate the proportion of carbohydrates and fat being sourced as fuel. Final outcome variables include: REE (kcal/day; kcal/kg/day; kcal/kg FFM/day); RER; Fat (%), CHO (%). Postprandial change in each measure was calculated as the area under the curve (AUC) of hourly metabolic measures after the test meal, with postprandial change from fasting calculated as the fasting AUC subtracted from the total postprandial AUC. The thermic effect of feeding (TEF) was calculated as the AUC for the percentage change in energy expenditure in response to the test meal.

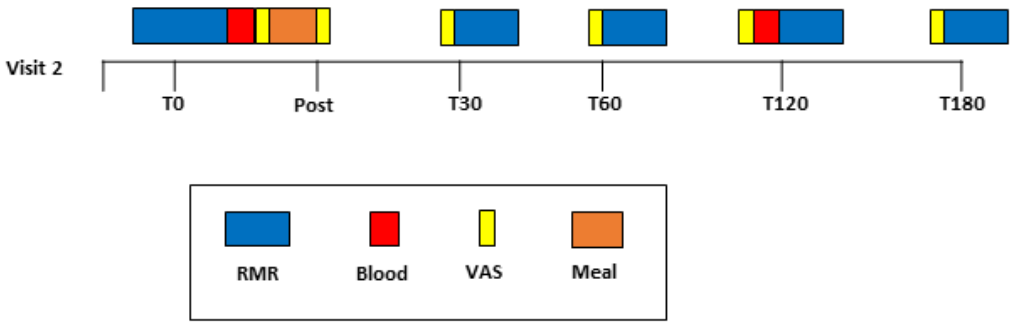


Fig 2.2: Timeline of measures taken during the metabolic testing in Visit 2. Time points are as follows: T0: fasting measure; Post: immediately post meal consumption; T30: 30 min post meal; T60: 60 min post meal; T120: 120 min post meal; T180: 180 min post meal. RMR: Resting Metabolic Rate; VAS: Visual Analog Scale.

Glucoregulatory Response

Following fasting RMR, a butterfly needle was inserted into the antecubital vein after sanitizing the area with an alcohol swab. Fasted blood samples were drawn into three separate tubes (±5ml each) to measure HbA1c, blood glucose and insulin. A second sample (2 x 5ml) was drawn at 120 min post

prandial to measure 2 hr blood glucose and insulin. Tubes for HbA1c and glucose were transferred to the refrigerator until collection that day. Insulin was kept standing at room temperature for 30 min before being centrifuged at 3000rpm at 4^{o}C for 10 min, then transferred to the refrigerator with the other samples until collection. Blood samples were collected and analysed by Lancet Laboratories. The generated report provided HbA1c (mmol/mol), blood glucose (mmol/l) and insulin (uU/ml); as well the homeostasis model assessment-estimated insulin resistance (HOMA-IR) index (Matthews et al., 1985) as a measure for insulin resistance and sensitivity The HOMA-IR is a reliable measure for insulin resistance, with a cut off value of >1.9 indicative of early insulin resistance and >2.5 of insulin resistance in adults (Keskin et al., 2005).

Subjective Appetite Measurement (Appendix 16)

During Visit 2 participants were asked to record their appetite (hunger, satiety, desire to eat) at fasting and post prandial timepoints using a validated visual analogue scale (VAS) (Flint et al., 2000). The VAS requires participants to make a mark along a horizontal 100 mm line to provide a rating for each question, with each end representing the extreme (e.g. 'not at all full' to 'extremely full'). VAS was taken before and immediately after the test meal and then post prandial at 30 min, 60 min, 120 min and 180 min.

Test Meal

Following fasting measurements participants consumed a test meal [Cabonara Pasta: 1712kJ (409.6 kcal) per 340g portion: 37.1g CHO, 17.9g fat]. The meal was designed to have an equal energy contribution of carbohydrate and fat (% energy contribution of meal: CHO=36.2%; Fat= 39.3%). Participants were asked to consume the full portion (340g) so that any physiological changes would reflect the response to the same energy dense meal. The timer was started as soon as they had finished the meal.

2.3.4 Executive Function and Working Memory Measures

Behavioural Rating Inventory of Executive Function in Adults (BRIEF-A) (Appendix 17)

BRIEF-A is a 75-item standardized measure which can be used as an initial screening tool to assess an adults executive function (Roth et al., 2005). Each of the 75 items are loaded on to one of nine subscales of Executive Function to produce three summary scales. Four subscales (Inhibit, Shift, Emotional Control and Self-Monitor) produced the summary scale 'the Behavioural Regulation Index' (BRI) and five scales (Initiate, Working Memory, Plan/Organize, Task Monitor, and Organization of Materials) produce the summary scale 'the Metacognition Index' (MI). Together the two summary scales produce a Global Executive Composite (GEC) score. Raw scale scores are transformed into T-

scores to provide information about the individuals score in relation to a standardized sample based on age and gender. Scores ≥ 65 are considered clinically significant and are indicative of executive dysfunction.

Computerized N-back Task

The n-back task is a letter-memory test that was conducted on a Mac Book Pro using Millisecond Software (Seattle, WA, United States) and using specific presentation software interface (Inquisit Lab, Millisecond Software, Seattle, WA, United States). The task involves the completion of 12 blocks of tasks. Each task involves a continuous stream of letters, with each letter appearing one at a time in the middle of the screen. During each task the participant has to identify the target letters according to the condition (level) at which the task is running. Participants identify these target letters using an allocated response button, in this case it was the 'A' key on the keyboard. There are 4 conditions (levels) which alternate over the 12 blocks of tasks (Fig 2.2). Under the easiest condition, 0-back, the first letter displayed on the screen is the 'target letter': every time the target letter appears on the screen the participant hits the response button. 0-back is the only condition with a pre-allocated target letter, the conditions thereafter do not have a specific target letter. The second condition is 1-back, for this condition participants respond every time a letter appears on the screen that is the same as the previous letter. In the 2-back condition, participants respond every time a letter appears on the screen that is the same as two letters previous. The final condition is 3-back, in which participants respond when a letter appears on the screen that is the same as three letters previous. Conditions alternate over the 12 blocks so that the participant completes three rounds of each. Between each block the test pauses to allow for participants to break until they are ready to continue.

The main outcome variables from the n-back task include total accuracy and latency. Accuracy was calculated as a percentage using the algorithm by Miller and colleagues (2009):

[1-((number of commission errors + number omission errors)/Total Number Targets)]*100

Where commission errors are the number of false responses (false hits) and omission errors are the number of missed responses. Latency (ms) was calculated as the time taken to respond to a correct target. Response time to incorrect targets were not used in the latency analysis as these responses may have flinch error or delayed responses to previous hits. The n-back task has been shown to have moderate test-restest reliability on accuracy performance while response time has shown high reliability (Hockey & Geffen, 2004).

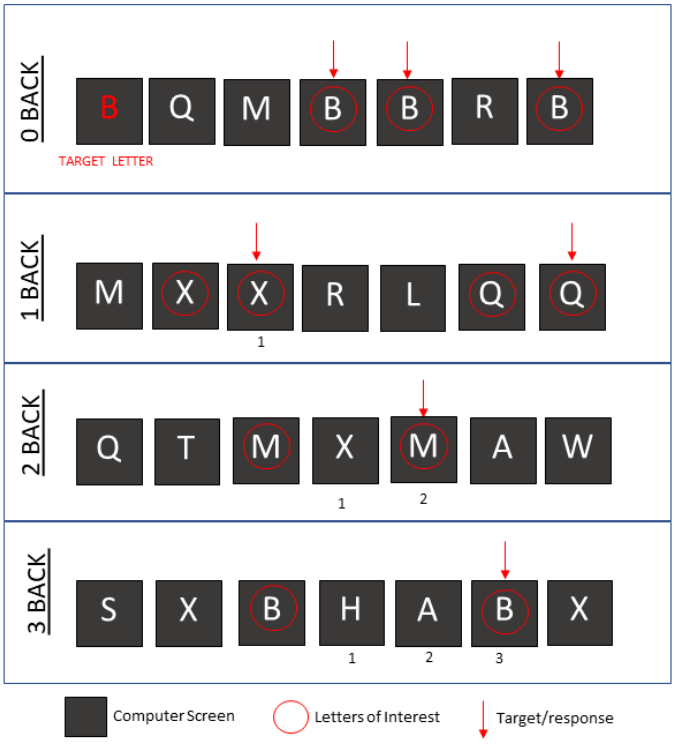


Figure 2.3: Visual representation of the four different N-back tasks. Each square represents the screen, with letters displayed one at a time starting from left and moving right. Red arrows represent where responses should occur for the corresponding condition.

Subliminal Images N-back Task

A subliminal images n-back task was conducted during a functional magnetic resonance imaging (fMRI) scan during Visit 3. This was not a standardized test but rather a self-developed n-back test to resemble the training stimulus used during the intervention. The subliminal n-back task comprises 12 alternating blocks of 1-back and 2-back tasks. Within each block, half of the letters are proceeded by a subliminal food image and the other half are proceeded by a neutral image (Fig 2.3). The order of neutral and food images alternates every two blocks (i.e. Block 1 and 2 will start with food images and end with neutral images; block 3 and 4 will start with neutral images and end with food images etc.). In between the showing of the image and letter, the screen is blanked with a centred cross. Each block is 70 352msec (1.17min), of this time the instruction screen is shown for 9015msec. Total time for picture-cross-letter-cross is 3066msec. Measures recorded were total accuracy (as calculated for computerized n-back); latency (ms); commission errors and omission errors.

Fig 2.4: Visual representation of the order of the subliminal images and n-back tasks completed during the fMRI. N: neutral images; F: Food images.

Digit Span (DS)

Participants performed two different digit span tasks: Visual digit span forward (fDS) and Visual digit span backward (bDS). The software assessment tool was conducted using Millisecond Software (Seattle, WA, United States); and tasks were conducted on a Mac book pro using specific presentation software interface (Inquisit Lab, Millisecond Software, Seattle, WA, United States). The task is based on recalling a sequence of numbers. Participants started with fDS, after which they were allowed a couple of minutes break before completing bDS.

The task starts with a three digits (between 1-9) displayed one at a time consecutively on the screen, before freezing on an input screen. Depending on which task is running, the participant then has to recall those digits either in the correct (forward) order, fDS, or in the reverse (backward) order, bDS, before selecting 'continue'. As participants correctly recall the digits, the digit list length (the number of digits displayed at one time consecutively) will increase by one digit. When participants make a mistake (i.e. one error) the list length stays at the same length for the next round; if the participant then makes a second mistake (i.e. two errors) the list length shortens by one digit. For both tasks participants complete 14 trials in which list lengths adjust according to the participants' performance. Within a list length no numbers are repeated and therefore only numbers (1-9) are displayed. The highest list length is therefore 9 digits.

There are four scoring variables produced from each task: Two Error Max Length (TE_ML), defined as the maximum list length recalled prior to making two consecutive errors; Two Error Total Trials (TE_TT), defined as the number of trials correctly recalled prior to making two consecutive errors; Max Length (ML), defines as the maximum list length recalled; and Mean Span (MS), defined as the estimated list length where 50% of the lists would be correctly reported.

2.4 Working Memory Training Intervention

WMT was conducted using a cell phone application called “Curb your Addiction” (C-Ya©) (Brooks et al., 2017). The C-Ya© application uses a modified version of the n-back task to train working memory; the modification being the use of subliminal food images that appear between letters. The images are used as both a target for addiction focus and to mimic distractions occurring in daily life. The application ranges from level 0 to 8, with each level corresponding to the level of “n” (i.e. Level 0 is 0-back; level 1 is 1-back etc.). Participants were provided with a cell phone for the intervention period with the application pre-loaded. They were asked to complete 4 sessions per week over the 6 weeks, resulting in a total of 24 sessions. As stated in Chapter 1, previous literature has shown that 20-25 sessions of WMT elicit adequate improvements in behaviour in overweight and obese individuals. One level was completed per session with only one session allowed per day. The session ran over 15 min, with a 1 min break at the 5 min and 10 min mark. Participants started the first session at level 0 and were only allowed to move to the next level once they had scored greater than 80% on their current level, this means that if they did not score above 80% on a particular day they would have to repeat the same level the following session. If their scores did not show improvement over the week, or were too low (<60%), they were asked to move down a level. C-Ya© provides the option to email the results of each session straight from the application, participants were therefore asked to e-mail their results to the researchers after each session as a means to monitor their progress and make sure the sessions were being completed (see supplementary figure S1 for example). At the end of the 6 weeks participants returned the cell phones to the researchers.

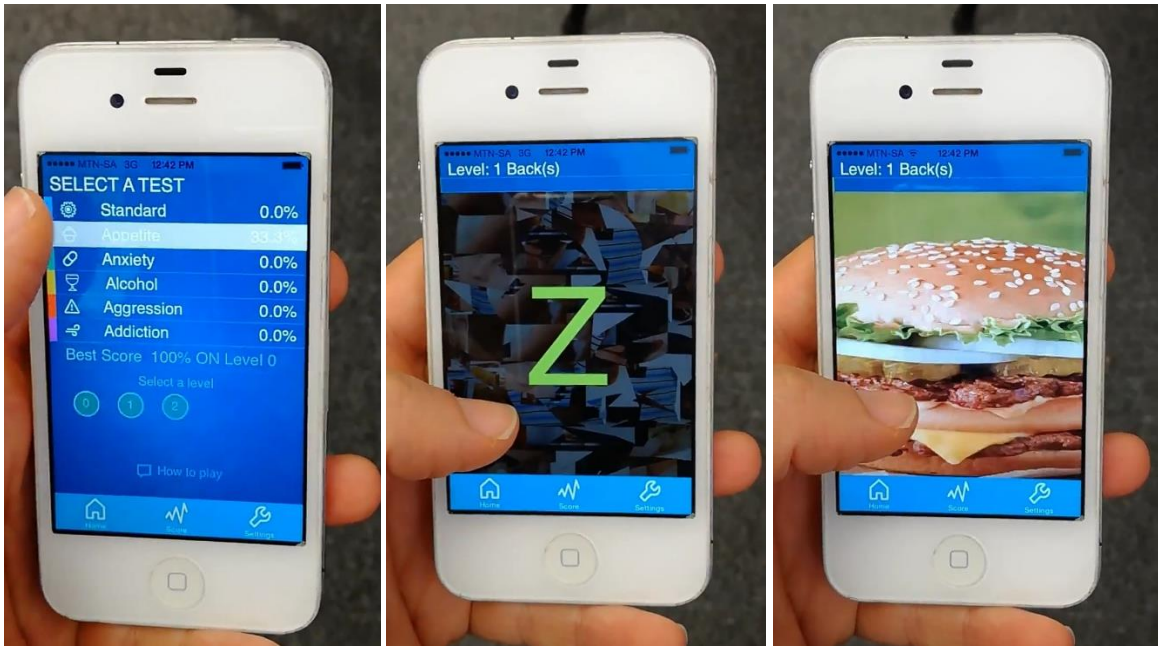


Fig 2.5: Images at different stages of using the CYA application. Images include the home screen where one choses the addiction focus, an image of the screen in which the letter appears across a mosaic and an image of one of the subliminal food images that appear during the test.

Table 2.1: Measures taken at each point of the experimental procedure

Screening	• Weight History • Health and Reproductive History (including S36 Survey) • Demographics
Baseline Tests	
Online Questionnaires	• BRIEF-A • WEL • Self-Efficacy • BDI
Visit 1	• Anthropometric measurements • N-back Task • DS (fDS; bDS) • Questionnaires: GPAQ; EDE-Q
Visit 2	• RMR • BIA • Blood tests • Questionnaires: Self-control Scale; EEQ
Visit 3	• Subliminal N-back (fMRI)
Intervention	
6 week Intervention	• C-Ya© WMT
Post-Intervention Tests	
Online Questionnaires	• BDI • BRIEF-A • Self-Efficacy • WEL
Visit 4	• Repeat first visit measures
Visit 5	• Repeat second visit measures
6 Month Follow Up Tests	
Online Questionnaires	• BRIEF-A • Self-Efficacy • WEL
Visit 6	• Fasting RMR • BIA • Anthropometric measurements • N-back task • DS (fDS; bDS) • Questionnaires (EEQ; TFEQ; Self-control Scale; GPAQ)

BRIEF-A: Behaviour Regulation Index of Executive function- adult version; WEL: Weight Efficacy Lifestyle Questionnaire; BDI: Becks Depression Inventory; DS: Digit Span (fDS: forward; bDS: backward); GPAQ: Global Physical Activity Questionnaire; EDE-Q: Eating Disorder Examination Questionnaire; RMR: Resting Metabolic Rate; BIA: Bioelectric

2.5 Statistical Analyses

All analyses were conducted using IBM SPSS version 26 for Windows (IBM Corp, Armonk, NY).Prior to statistical analysis, all variables were tested for normality using the Shapiro-Wilk test. Statistical tests were then chosen accordingly based on whether data was parametric or non-parametric. Full details on statistical analyses and tests conducted are provided under each experimental chapter.

Statistical significance was accepted at $p < 0.05$, however, as Greenland and colleagues (2016) state "Statistical significance is neither necessary nor sufficient for determining the scientific or practical significance of a set of observations." This is a view supported by the American Statistical Association (Wasserstein & Lazar, 2016). Taking into consideration the sample size statistical significance was not the only focus of determining practical significance. For this reason the p-value was also evaluated as a continuous measure and statistical significance was not used as the final cut-off for determining the presence or absence of an observation, but merely as a guide to the existence of a difference. Therefore the outcome of the statistical procedures were just one of the evaluated considerations when examining the results, other considerations included distribution of the data and the context behind the measures.

Chapter 3 Formative Analysis

The behavioural, physiological and cognitive differences between reduced-obese women and stable-weight controls to determine the possible compensatory responses to weight loss

3.1 Introduction

As detailed in Chapter 1, weight loss results in various physiological and psychological changes that may increase susceptibility to weight regain. It's important to identify what challenges these changes may pose to weight maintenance in order to target therapies towards combatting these effects.

For instance, during and after weight loss, there is a physiological drive to regain the weight which was lost. When weight loss occurs, the body activates physiological responses in order to restore 'balance' (MacLean et al., 2015). These physiological factors include the lowering of energy expenditure through increased energy efficiency and an increase in appetite through changes in appetite and satiety hormones, these changes then influence the impulsive system to increase ones food intake and reduce activity (Melby et al., 2017). To overcome these responses, behaviour during the weight maintenance phase needs to reflect that of the behaviour that was enforced during the weight loss itself, however, at this point the cost of adherence to physical regimes and diet begin to outweigh the benefits as there is no longer sustained positive feedback (MacLean et al., 2015).

It is then expected that in order to maintain their weight, those who have lost weight will have to maintain different eating and exercise behaviours than those who have never experienced weight loss. However, enforcing these behaviours and going against physiological urges may lead to a change in eating and food-related thoughts. Calorie restriction results in 'physiological deprivation' which further causes a change in appetite hormones and results in a heightened brain 'reward and motivation' response to food cues, further enforcing the feeling of addiction (Lawson et al., 2011; Stice et al., 2013). Restriction in itself activates the hedonic appetite system which increases an appetite for palatable foods; when resisting these cravings this may then produce feelings of 'perceived deprivation' (Lowe & Levine, 2005). Together physiological and psychological deprivation can lead to the development of negative eating and food-related thoughts and behaviours. This could include feeling more restrained over ones food intake, having more eating concerns, or experiencing dietary disinhibition. Although restraint over food intake is needed to lose weight, evidence also shows it can

lead to the development of binge-eating disorders and a negative relationship with food (Stroebe et al., 2008; Tuschl, 1990).

The discipline and self-control enforced during and after weight loss therefore requires the utilisation of the executive system. Executive function has been shown to play an important role in overcoming the physiological and psychological challenges of weight loss to ensure long-term weight-loss success. Those with greater executive function will be able to exhibit higher cognitive restraint over their food intake, while those with lower executive function may give in to their hunger (Hege et al., 2013). Although having a higher executive function is associated with successful weight loss, evidence is mixed about the effect of weight loss itself on executive function. While reduced adiposity and utilisation of the executive system through dietary restraint is thought to strengthen executive function, some evidence suggests the cognitive overload through sustained restraint may actually weaken it (Clarkson et al., 2011; Green et al., 1997; Hester & Garavan, 2005). As executive function may be an important component in overcoming the physiological and behavioural compensatory responses to weight loss, and thereby an important component in successful weight-loss maintenance, it is important to determine how it may be affected by weight loss itself.

3.2 Aims and Objectives

This chapter aimed to (1) describe the behavioural, physiological and cognitive differences between reduced-obese women and stable-weight women; and (2) determine whether time since weight loss has an influence on these factors. The specific objective of the analysis was to identity the compensatory responses that might occur with significant weight loss.

3.3 Methods

3.3.1 Participants

Participant recruitment and criteria are described in chapter 2. Twenty-nine women between the ages of 25 to 45 years (M= 35.5 ± 5.8 years) were recruited in the crossover study (Fig 3.1). Participants were classified as one of two conditions: 'Reduced-obese' (RED; n=23), those who had lost a significant amount of weight in the two years before recruitment; or 'Stable weight' (Stable; n=6), those who had no significant weight loss or weight gain history. The Stable condition was age-and-BMI matched to the RED condition. Conditions were further divided into three groups. The Stable condition consisted of the stable weight individuals mentioned above. The RED condition was separated into two groups according to 'time since weight loss': 'Recently Reduced' (RED-R; n=15), participants who had lost a

significant amount of weight (>10%) in the 6 months before recruitment; and 'Stable Reduced' (RED-S; n=8), participants who had lost a significant amount of weight in the 2 years before recruitment, but had remained weight stable in the 6 months before recruitment.

There was missing data for a total of six participants. Due to unforeseen circumstances four participants were unable to continue with testing after visit one; one participant dropped out of the study after visit two; and one participant completed visit three but equipment malfunction meant that the N-back data was lost for this visit.

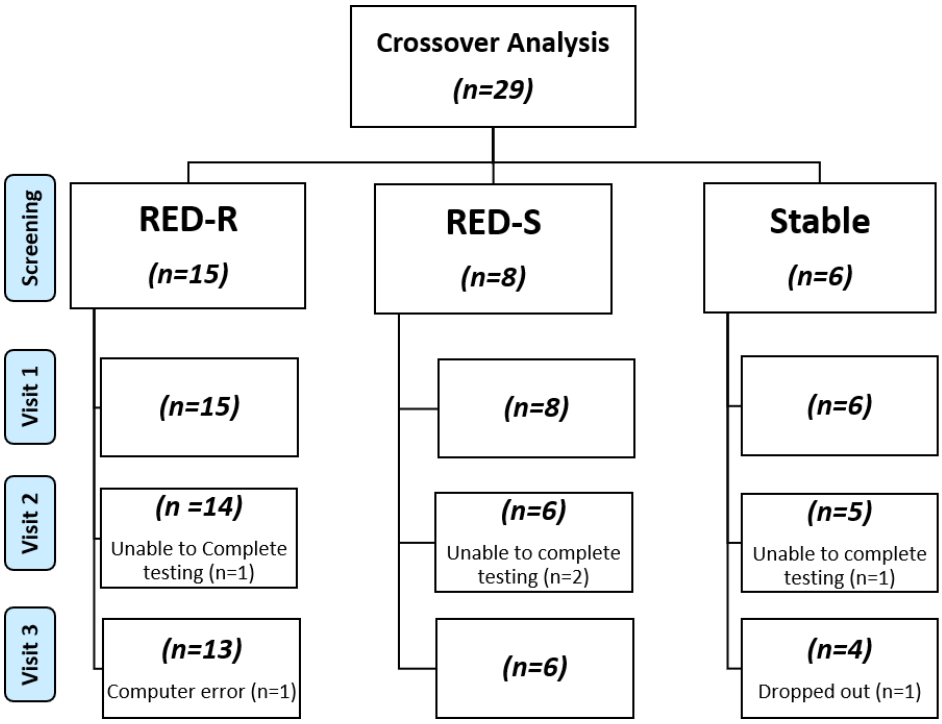


Fig 3.1: Flow chart indicating participant numbers at each point of baseline testing within each group. RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight.

3.3.2 Measures

All baseline measures used for comparison between conditions and groups are described in Chapter 2 (see sections 2.1; 2.2; 2.3)

3.3.3 Statistical Analysis

All analyses were conducted using IBM SPSS version 26 for Windows (IBM Corp, Armonk, NY). All variables within each group were tested for normality using the Shapiro-Wilk test. For comparisons between conditions (RED vs Stable) and between the RED groups (RED-R vs RED-S) the Independent-t test was used for parametric data, while the Mann-Whitney U test was used for non-parametric data.

For comparisons between groups (RED-R vs RED-S vs Stable) the One-way ANOVA was used for parametric data, with Bonferroni for post-hoc analysis; while the Kruskal-Wallis test was used for non-parametric data. Results are expressed as 'mean ± standard deviation' for normally distributed data, while 'median (interquartile range (IQR))' are expressed for non-parametric distributed data. Statistical significance was accepted at $p < 0.05$.

3.4 Results

3.4.1 Participant Characteristics

Participant characteristics and weight loss history are presented in Table 3.1. Group analysis showed that the only significant difference in anthropometric measures between groups was a difference in weight ($F(2,26)= 6.299$, $p=0.006$), with the RED-R group having a significantly higher weight than the Stable group (M=76.1 ± 8.1 vs 64.3 ± 6.2 kg, $p= 0.005$), however, RED-R was not significantly higher than RED-S (M= 70.6 ± 5.1 kg; $p= 0.254$). There was no significant difference in BMI between groups ($F(2,26)= 1.343$, $p= 0.279$).

Table 3.1: Participant Characteristics displayed per group and condition (mean values ± standard deviations)

	STABLE	REDUCED		
		RED total	RED-R	RED-S
	(n= 6)	*(n= 23)*	*(n= 15)*	*(n= 8)*
Age (yrs)	35.8 ± 6.6	35.4 ± 5.8	35.5 ± 4.6	35.3 ± 7.9
BMI (kg/m²)	25.6 ± 3.8	28.0 ± 3.0	28.2 ± 3.3	27.6 ± 2.3
Waist (cm)	78.1 ± 5.4	83.8 ± 8.6	85.4 ± 9.9	80.9 ± 4.6
WHtR	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.0
BF (%)	31.8 ± 7.8	33.2 ± 6.2	33.0 ± 6.7	33.7 ± 5.1
Weight Loss History				
HAW BMI (kg/m²)		35.7 ± 3.3	35.3 ± 2.6	36.4 ± 4.5
Time Since HAW (yrs)		3.0 ± 2.6	2.7 ± 2.7	3.5 ± 2.5
Total Wt lost (%)		21.2 ± 9.5	20.3 ± 7.3	22.9 ± 13.0
6 month Wt loss (%)			13.8 ± 5.4	0.7 ± 1.1

RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight; BMI: Body mass index; Waist: Waist circumference; WHtR: Waist-to-height ratio; HAW: Highest adult weight before weight loss; Wt: Weight; 6 month Wt loss: the percentage of weight lost within the 6 months prior to testing.

There was no significant difference between RED-R and RED-S regarding total weight lost since HAW ($t(21)= -0.607$, $p= 0.551$) or time since HAW ($t(21)= -0.671$, $p= 0.509$). HAW was defined as the weight they were at before they began their weight loss journey. Together the RED condition had lost an average of 20.7 ±10.5 kg which amounted to a 21.2 ±9.5 % reduction in body weight. Of the total weight lost, RED-R had lost 13.8 ±5.4 % of their weight within the 6 months before recruitment. Although the time since they began their weight loss was not significantly different, the mean time for RED-S (3.5 ±2.5 yrs) was approximately 9 months longer than RED-R (2.7 ±2.7 years), which would account for the 6 months stable weight period since they reached their goal weight.

In addition, conditions and groups did not differ significantly on any variables addressing demographics, education, medical history, health or socio-economic status.

3.4.2 Measures of Eating Behaviour and Food-related Thoughts

There was no significant difference between groups on any measures of eating behaviour or food-related thoughts. The median scores obtained on the Eating Disorder Examination Questionnaire (EDE-Q) are displayed in Fig 3.2. There was no significant difference between the RED-R and RED-S group on any of the factors of the EDE-Q. Together, the RED condition appeared to score higher than the stable condition across most factors (Restraint: $U= 35$, $p= 0.071$; Eating concern: $U= 41.5$, $p= 0.142$; Shape concern: $U= 39$, $p= 0.114$; Weight concern: $U= 32$, $p= 0.047$; Total score: $U= 35$, $p= 0.071$). The RED condition displayed a higher total score than the Stable condition (2.6 (1.0-3.2) vs 0.73 (0.3-1.7) resulting in the RED condition scoring within the borderline range indicative for presence of eating-disorder pathology (cut-off for normal samples ≥ 2.5 vs obese samples ≥ 3).

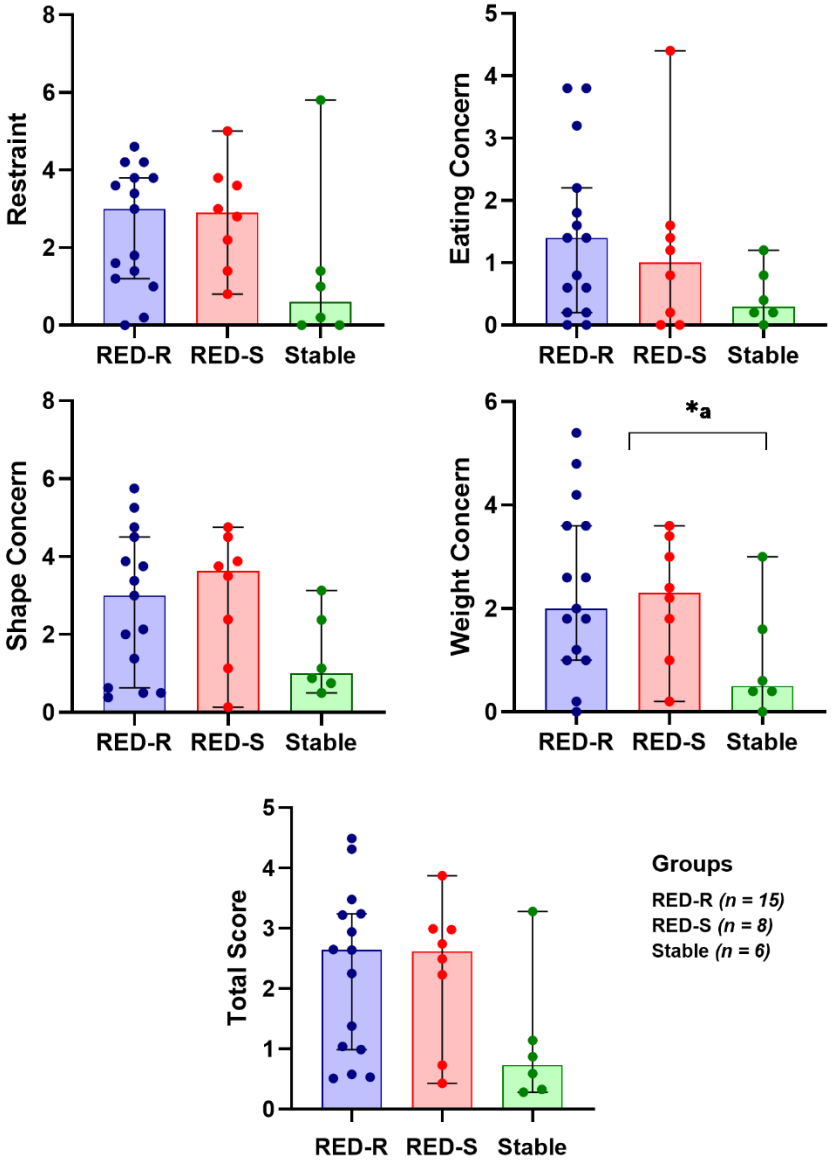


Fig 3.2: Self-reported eating-disordered behaviour displayed per group, as measured by the Eating Disorder and Examination Questionnaire (EDEQ). The four Factors, Restraint, Eating Concern, Shape Concern and Weight concern contribute towards the total score. Dots represent individual data points; bars represent median scores; error bars represent 95% confidence interval. RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight.

*** p < 0.05, where (a) conditions significantly different.**

There were no significant differences between conditions on measures of weight efficacy (t(27)= 0.336, p= 1.000) or emotional eating (t(23)= 1.080, p= 0.291). Although the RED-R group scored higher on the EEQ resulting in the mean falling within the Emotional Eater category (≥11) (12.6 ± 4.0) compared to RED-S (9.0 ± 3.9; p= 0.077) and the Stable group (9.0 ± 6.6; p= 0.157) (Fig 3.3).

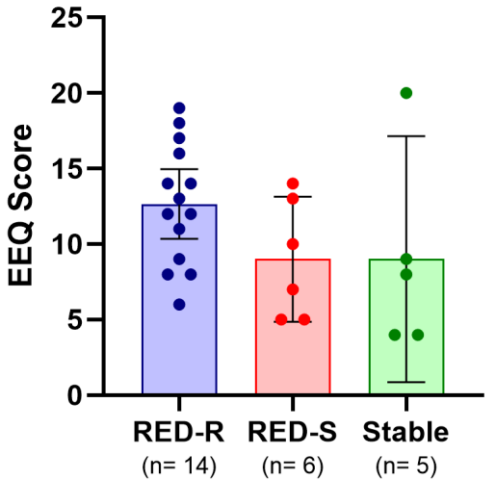


Fig 3.3: Emotional-eating behaviour displayed per group, as measured by the Emotional Eater Questionnaire (EEQ). Dots represent individual data points; bars represent mean scores; error bars represent 95% confidence interval. Scores > 11 indicate emotional eater behaviour. RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight.

3.4.3 Measures of Depression, Self-control and Self-efficacy

There was no significant difference between conditions in self-control (U= 59, p= 0.575) or self-efficacy (U= 58, p= 0.581) (See supplementary material S1 for full descriptive). While no difference was observed between groups in terms of depression ($\chi^2(2)= 1.843$, p= 0.164) as measured by the BDI, the RED condition did appear to score higher on the BDI compared to the Stable condition (10 (5-17) vs 4.5 (0-10); U= 36, p= 0.080), however, they were still within the minimal-mild range for depressive symptoms (<19).

3.4.4 Physical Activity and Energy Metabolism

Physical Activity

There was no significant difference in self-reported physical activity between groups or conditions (See supplementary material S2 for full descriptive). The RED condition report total activity of 290 min/week (180-600 min/week), while the Stable condition reported total activity of 350 min/week (184-1114 min/week) (U= 81, p= 0.546). From the total activity, the RED condition reported vigorous activity of 80 min/week (0-180 min/week), while the Stable condition reported vigorous activity of 150 min/week (90-338 min/week) (U= 90, p= 0.278). On sedentary time the RED condition reported time spent in sedentary of 5040 min/week (3360-5460 min/week) and the stable condition 5460 min/week (2100-5933 min/week)(U= 72.5, p= 0.854).

Resting Metabolic Rate

There was a significant difference in the time since last meal (TLM) at group analysis ($F(2,21)= 5.180$; $p= 0.015$). The "time since last meal" was defined as the duration of fasting prior to the resting metabolic rate measurement. Post-hoc analysis showed that RED-S (13.37 ±1.37 hrs) fasted on average 2hrs more than the RED-R (11.64 ±1.09 hrs) and Stable (11.35 ±1.38 hrs) groups. For this reason it was decided to do ANCOVA with TLM as a covarying factor. With this adjustment there was no significant difference in the fasting state between conditions or groups (Table 3.2).

Following ingestion of the test meal, there was a significant difference between groups and conditions in their post-prandial metabolic response (Table 3.2). There was a significant difference between groups in the percentage change in energy expenditure in response to the meal (TEF%) ($F(2,21)= 0.025$, $p=0.025$). Bonferroni correction showed that this difference was found to be greatest between the Stable group and RED-S, with Stable having a much higher TEF than RED-S ($p= 0.021$). Together, RED condition displayed a lower TEF compared to the Stable condition ($t(22)= -2.520$, $p=0.020$).

There was no significant difference between groups in total post-prandial energy expenditure, however, there was a significant difference between groups in post-prandial change in energy expenditure from fasting (‡REE (kcal/kg): $F(2,21)= 6.625$,$p= 0.006$; ‡REE (kcal/kg FFM): $F(2,21)= 5.602$, $p= 0.011$). Post-hoc analysis showed that both RED-R and RED-S had a significantly lower energy expenditure change from fasting per kg bodyweight than the Stable group ($p= 0.028$ and $p=0.005$), while RED-S had significantly lower energy expenditure change from fasting per kg FFM than Stable ($p=0.009$). There was no significant difference between RED-R and RED-S in response to the meal. When comparing conditions the stable condition displayed a greater total post-prandial change in energy expenditure compared to RED (REE (kcal/kg): $t(22)= -2.133$, $p= 0.044$); REE (kcal/kg FFM): $t(22)=-2.276$, $p= 0.033$), as well as a greater change in energy allocation from fasting (‡REE (kcal/kg): $t(22)= -3.274$, $p= 0.003$; ‡REE (kcal/kg FFM): $t(22)= -2.962$, $p= 0.009$).

Change in RER is displayed in Fig 3.4. Group analysis showed that the greatest difference in RER between the groups was at 120min ($F(2,21)= 5.993$, $p= 0.009$) and 180min ($F(2,21)= 3.025$, $p=0.070$). With RED-R and RED-S being significantly different to stable at 120min ($p= 0.017$ and $p= 0.011$). The RED condition had a significantly higher RER at 60 min ($t(22)= 2.090$, $p= 0.048$), 120 min ($t(22)= 3.420$, $p= 0.002$) and 180 min ($t(22)= 2.292$, $p= 0.032$) post-meal consumption. The greatest difference at 120 min was seen in the substrate oxidation, with the Stable group reaching a mean of 99.4 ± 0.4 % fat oxidation, while RED reached a mean of 77.6 ±14.9 % fat oxidation ($t(19.124)= -6.535$, $p< 0.001$).

Table 3.2: Metabolic measurements displayed per group and condition (mean values ± standard deviations)

	Stable	Reduced			
		RED	RED-R	RED-S	
	(n= 4)	*(n= 20)*	*(n= 14)*	*(n= 6)*	
Fasting					
RER	0.76 ± 0.09	0.77 ± 0.04	0.77 ± 0.05	0.78 ± 0.04	
REE (kcal/day)	1378 ± 129	1467 ± 156	1520 ± 157	1344 ± 49	
REE (kcal/kg FFM/day)	31.8 ± 2.7	30.2 ± 2.9	30.4 ± 3.4	29.8 ± 1.7	
Fat (%)	79.8 ± 28.5	77.1 ± 15.0	78.3 ± 15.9	74.4 ± 13.7	
Postprandial					
TEF (%)	21.1 ± 6.3	13.6 ± 5.3	14.8 ± 5.8	10.9 ± 2.7	**ab*
REE (kcal/kg) ‡	0.6 ± 0.2	0.3 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	***ab*
REE (kcal/kg FFM) ‡	0.8 ± 0.2	0.5 ± 0.2	0.6 ± 0.2	0.4 ± 0.1	***a*b*

RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight; RER: Respiratory exchange ratio; REE: Resting Energy Expenditure; FFM: Fat-free mass; TEF: Thermic effect of feeding.

‡ Postprandial three-hour change from fasting measures, calculated as AUC of hourly fasting metabolic measures subtracted from total hourly metabolic measures, following ingestion of the test meal.

*** p < 0.05, ** p < 0.01, where (a) conditions significantly different; (b) groups significantly different.**

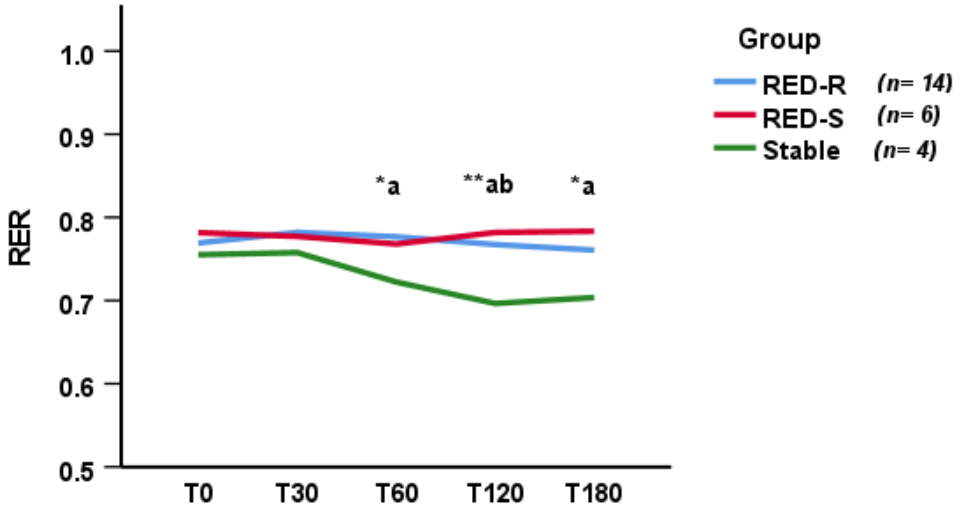


Fig 3.4: Respiratory Exchange Ratio (RER) measures, displayed per group per time point. Time points are as follows: T0: fasting measure; T30: 30 min post meal consumption; T60: 60 min post meal; T120: 120 min post meal; T180: 180 min post meal. Lines represent mean measures at each time point for each group. RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight.

*** p < 0.05; ** p < 0.01, where (a) conditions significantly different; (b) groups significantly different.**

3.4.5 Glucoregulatory Response and Appetite

Due to the difference in TLM at group analysis, ANCOVA was used for fasting measurements with TLM as a covarying factor. There was no significant difference in fasting HbA1c, fasting blood glucose,

fasting insulin or HOMA-IR between conditions or groups (see Table 3.3). None of the participants displayed signs of insulin resistance as observed by HOMA-IR, which was within the normal range for all groups (<1.9). RED-S did have a mean HOMA-IR less than 1 which is indicative of insulin sensitivity. There was also no significant difference in postprandial blood glucose or insulin between groups or conditions.

There was no significant difference between groups in appetite measures at fasting or following meal consumption. For all participants there was a general decline in hunger, and desire to eat, as well as an increase in satiety observed after the meal (Fig 3.5). There was, however, a significant difference in hunger between conditions at 60 min postprandial (U= 80.5, p= 0.035), with RED feeling less hunger than Stable (5.45 ±10.03 vs 13.80 ±10.50).

Table 3.3: Glucoregulatory response and Appetite Regulating Hormone displayed per group and per condition (mean values ± standard deviations)

	Stable	Reduced		
		RED	RED-R	RED-S
	(n= 5)	*(n= 20)*	*(n= 14)*	*(n= 6)*
HbA1c (mmol/mol)	36.4 ± 4.2	34.2 ± 3.7	34.9 ± 3.6	32.3 ± 3.7
Fasting Glucose (mmol/l)	4.8 ± 0.4	4.7 ± 0.4	4.8 ± 0.3	4.4 ± 0.5
2hr Glucose (mmol/l)	4.7 ± 0.9	4.7 ± 0.4	4.7 ± 0.4	4.8 ± 0.4
Fasting Insulin (uU/ml)	5.3 ± 1.9	6.0 ± 3.3	6.8 ± 3.4	4.1 ± 2.1
2 hr Insulin (uU/ml)	13.1 ± 5.6	18.6 ± 15.1	18.9 ± 16.8	17.9 ± 12.2
HOMA-IR	1.12 ± 0.36	1.28 ± 0.73	1.46 ± 0.75	0.85 ± 0.50

RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight; HbA1c: Hemoglobin A1c; HOMA-IR: Homeostatic Model Assessment of Insulin Resistance

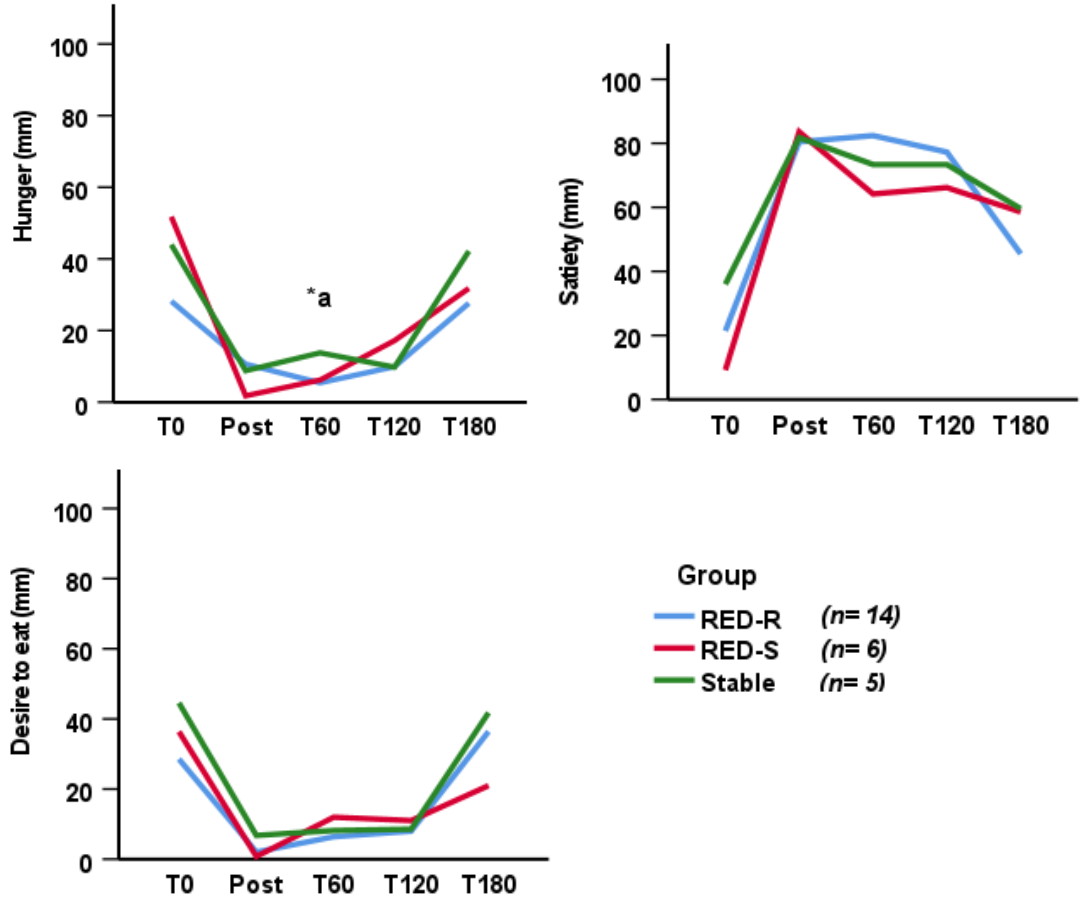


Fig 3.5: Subjective appetite measurements (mm) displayed per group per time point. Time points are as follows: T0: fasting measure; Post: immediately post meal consumption; T60: 60 min post meal; T120: 120 min post meal; T180: 180 min post meal. Appetite measures were that of Hunger, Satiety and Desire to eat. Lines represent mean measures at each time point for each group. RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight.

*** $p < 0.05$, where (a) conditions significantly different.**

3.4.6 Executive Function and Working Memory

BRIEF-A

Out of the 29 participants, five scored ≥65 on the global executive composite (GEC), indicating possible executive dysfunction (RED-R (n=2); RED-S (n=2); Stable (n=1)). There was no significant difference between groups on any of the subscale or summary scales (See supplementary material S3 for full descriptive). Additionally conditions did not significantly differ on any of the subscales or the GEC (U= 47.5, p= 0.254), the BRI (U= 36, p= 0.080) or the MI (U= 59.5, p= 0.618) summary scales (Fig 3.6).

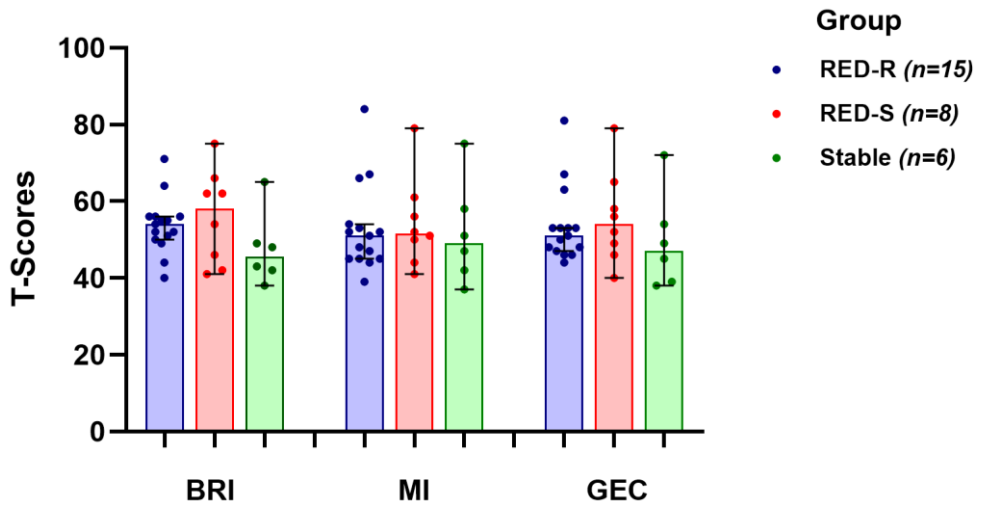


Fig 3.6: BRIEF-A summary t-scores displayed per group. T-Scores ≥ 65 are within clinical range and are indicative of executive dysfunction. Dots represent individual data points; bars represent median scores; error bars represent 95% confidence interval. RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight; BRI: Behavioural regulation index; MI: Metacognition index; GEC: Global executive composite.

N-back

There was no significant difference between groups or conditions in any measures of the n-back (Table 3.4). Mean accuracy on the n-back task was 72.2 ±15.5% and mean latency for correct responses was 680ms (586-826 ms).

Table 3.4: Computerized N-back task displayed per group and condition (mean values ± standard deviation; median values (IQR))

	Stable	Reduced		
		RED total	RED-R	RED-S
	(n= 6)	*(n= 23)*	*(n= 15)*	*(n= 8)*
Accuracy (%)	67 ± 19	74 ± 15	77 ± 12	68 ± 19
Latency (ms)	784 (650-941)	619 (580-748)	684 (592-740)	591 (543-839)

Measures taken are percentage accuracy and response time to correct hits (latency). RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight.

Subliminal Image N-back

There were no significant differences between groups or conditions on any of the outcome measures of the fMRI n-back task, this was true even when comparing outcomes of food vs neutral stimuli (Table 3.5).

Table 3.5: Subliminal image N-back task, conducted during fMRI, displayed per group and condition (Median values (IQR)).

	STABLE	REDUCED		
		RED total	RED-R	RED-S
	(n= 4)	*(n= 19)*	*(n= 13)*	*(n= 6)*
Food				
Accuracy (%)	**94** (92-96)	**88** (76-96)	**88** (74-96)	**90** (67-93)
Latency (ms)	**770** (674-889)	**720** (658-776)	**749** (637-867)	**685** (653-739)
Neutral				
Accuracy (%)	**94** (92-99)	**92** (83-100)	**92** (83-100)	**92** (61-97)
Latency (ms)	**672** (616-845)	**705** (640-798)	**728** (654-951)	**684** (618-731)

Alternating n-back task with blocks of either subliminal food images (Food) or subliminal neutral images (Neutral). Measures taken are percentage accuracy and response time to correct hits (latency). RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight.

Digit Span

There was no significant difference between groups or conditions on any measures of the DS (Table 3.6). The difference between conditions on the DS was as follows: fTE_ML (U= 80, p= 0.581); fTE_TT (U= 77, p= 0.694); fML (U= 79.5, p= 0.581); fMS (U= 74.5, p= 0.773); bTE_ML (U= 54.5, p= 0.445); bTE_TT (U= 57, p= 0.546), bML (U= 41, p= 0.142); bMS (U= 43.5, p= 0.174).

Table 3.6: Digit Span Measures displayed per group and condition (Median values (IQR))

	Stable	Reduced		
		RED total	RED-R	RED-S
	(n= 6)	*(n= 23)*	*(n= 15)*	*(n= 8)*
Forward Digit Span				
fTE_ML	7 (5-8)	6 (6-7)	7 (5-8)	6 (6-7)
fTE_TT	6 (3-8)	5 (4-6)	5 (4-7)	5 (4-6)
fML	8 (7-8)	7 (6-8)	7 (6-8)	7 (6-8)
fMS	7 (6-7)	7 (6-7)	7 (5-8)	7 (6-7)
Backward Digit Span				
bTE_ML	5 (4-6)	5 (4-7)	5 (4-7)	6 (5-7)
bTE_TT	4 (3-7)	4 (4-6)	4 (4-6)	6 (4-6)
bML	6 (5-7)	7 (6-8)	6 (5-8)	7 (6-8)
bMS	5 (4-6)	6 (5-7)	6 (4-7)	7 (6-7)

RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight; TE_ML: Two error maximum length; TE_TT: Two error total trials; ML: Maximum length; MS: Mean span.

3.5 Discussion

The current analysis aimed to describe the behavioural, physiological and cognitive differences that may exist between reduced-obese women and those who have remained stable weight. Importantly, the analysis also aimed to determine whether time since weight loss had an effect on any of these factors. This was done by dividing the RED condition into recently reduced-obese and stable reduced-obese. The main finding was that both groups of reduced-obese women displayed a stunted post-prandial metabolic response compared to their stable-weight controls. While obese-reduced women showed some evidence of different eating and food-related behaviours compared to stable-weight controls, there were no other observed differences in self-control, self-efficacy or executive function between the conditions.

The greatest difference found between reduced-obese women and stable-weight controls was in their post-prandial metabolic response. It is important to note, however, that this analysis had a small sample size of stable-weight controls, so while there was significance there is a high chance of these findings being the result of a type II error due to the small sample size. For this reason our discussion relies heavily on previous evidence which has found similar results and therefore serves to corroborate our findings. Although fasting metabolic rate was similar across our sample, food consumption of an identical meal in terms of weight, macronutrient and energy composition, generated a greater thematic effect of feeding in the stable-weight women. This would indicate that obese-reduced women were more energy efficient as they metabolised less energy from their meal, despite consuming the same amount of calories. This is in line with previous findings that have found reduced TEF following weight loss (Camps et al., 2013; Nelson et al., 1992). This adds onto the theory that there is a physiological attempt to conserve energy after weight loss so that the body can “restore balance”. It also appeared that reduced-obese women had signs of reduced metabolic flexibility, which is the ability to transition between substrate oxidation according to substrate availability (Galgani et al., 2008). Despite an equal ratio fat and carbohydrate meal, the reduced-obese women showed minimal change in their substrate oxidation, while stable-weight controls showed an increase in fat oxidation in response to the meal. Low fat oxidation results in greater carbohydrate utilisation, which promotes greater fat storage at times when a positive energy balance may occur (Raben et al., 1994). This could put obese-reduced women at a metabolic disadvantage and predispose them to a greater likelihood of weight regain, due to the ease of fat storage, compared to women that have never experienced weight loss. Importantly both reduced-obese groups displayed similar metabolic profiles in response to the meal, indicating that 6 months or more of weight maintenance following weight loss did not affect the energy efficiency of the stable reduced-obese group.

Interestingly, there did not appear to be a difference in appetite between reduced-obese and stable-weight women, despite their postprandial difference in energy metabolism. To evaluate whether there was a change in the hormonal regulation of appetite, we observed whether reduced-obese women showed a difference in their postprandial insulin response compared to stable-weight women. Insulin is an appetite regulatory hormone that is released after food intake to suppress appetite, and it's levels have been shown to vary with adiposity, those with greater adiposity release more insulin (Austin & Marks, 2009; Flint et al., 2007; Verdich et al., 2001). While there was not a significant difference in fasting insulin or HOMA-IR, it did appear that the reduced-obese women who had maintained their weight loss over 6 months did have a much lower HOMA-IR than both stable-weight women and recently reduced-obese women, indicating potentially better insulin sensitivity. This is in line with previous research that has shown that weight loss results in greater insulin sensitivity in those who are able to maintain this weight loss over time (Clamp et al., 2017). Yet, there was no significant difference between stable-weight and reduced-obese women's postprandial insulin response, which may explain why hunger, desire to eat and satiety, as measured by VAS, saw very little to no difference among groups and why substrate oxidation was similar between both reduced-obese groups.

Within the sample there was no differences in self-efficacy or feelings of self-control, although all three groups appeared to score on the lower end of the self-control scale. Depressive symptoms and emotional eating indicated some differences between reduced-obese women and stable-weight women, with reduced-obese women scoring higher in these factors. Research shows that obese individuals are more likely to suffer from depression (Barry et al., 2008; Petry et al., 2008), emotional eating (Ganley, 1989), and exhibit less self-control (Fan & Jin, 2014) than their leaner counterparts. Yet, weight loss itself has been shown to improve these outcomes (Braden et al., 2016; Choo & Kang, 2015; Clark et al., 1996; Will Crescioni et al., 2011), which may mean that these factors were recently improved in the reduced-obese group, resulting in reduced variance between conditions. Most notably the reduced-obese women showed signs of greater eating-disordered behaviour compared to stable-weight women, such as higher feelings of restraint and eating concern. While restraint is an important factor in weight maintenance, with higher dietary restraint associated with greater likelihood of long-term weight maintenance (Vogels et al., 2005), research shows that inhibition of appetite needs, such as that experienced by dieters, results in more obsessive thoughts related to eating and food which may put them at risk for weight gain (Hart & Chiovari, 1998). It is also important to note that while the Stable weight women did not have a history of weight gain or loss, they were still within the BMI range of overweight. As evidence shows that higher BMI is associated with greater

dieting and body dissatisfaction (McLean et al., 2010) it is unsurprising that despite being stable weight these women may also exhibit disordered eating and food-related behaviours.

There did not appear to be a difference in executive function between reduced-obese women and those of stable weight as measured by performance-based and subjective executive function measures. There could be many reasons for why groups showed similar measures. For instance one reason could be that the weight loss itself improved the executive function and working memory capacity of the reduced-obese women to that of a stable-weight individual, as weight loss has been shown to improve executive function in various populations (Brinkworth et al., 2009; Bryan & Tiggemann, 2001; Green et al., 2005; Halyburton et al., 2007; Siervo et al., 2012). In opposition, it could also be that executive function was slightly impaired in the stable-weight group, as majority of the stable weights had a BMI in the range of overweight. Overweight participants have also been implicated with significant deficits in some areas of executive function, such as inhibition and working memory (Y. Yang et al., 2018). Without knowing individuals executive function measures before the weight loss occurred, and with such a small stable weight group, it is difficult to theorise as to why no difference was observed. Alternatively it could be that the tests were not sensitive enough to pick up these differences.

Importantly, there did not appear to be any differences between those who had maintained their weight loss over a minimum of 6 months and those who had lost a significant amount of weight within the 6 months before recruitment. While the recently reduced-obese did appear to display greater emotional eating than the stable reduced-obese, both groups displayed a similar difference in post-prandial metabolic response and eating-disordered behaviours compared to the stable-weight women. This provides evidence that the physiological and behavioural changes that occur with weight loss are still very present between 6 months to one year after weight loss. This means that there is still a physiological drive and risk to regain weight, as seen by greater energy efficiency, reduced metabolic flexibility and similar disordered-eating behaviour. Interestingly there was no difference in executive function between these groups, which would imply that the weight-maintenance period experienced by the stable obese-reduced women did not have a visible effect on executive function. Some have suggested that diet and weight loss itself can negatively impact executive function as restrictive eating and daily self-monitoring are thought to cause cognitive strain (Clarkson et al., 2011; Green et al., 1997; Hester & Garavan, 2005; Kemps et al., 2005; Kemps & Tiggemann, 2005).

It is important to note that limitations to this analysis may have had an influence over the findings or lack of findings attained. A prime limitation to this analysis was the small sample size, especially within the stable-weight controls. The reduction in the number of participants during the metabolic testing

and fMRI n-back task further reduced the size of the stable-weight group, which may have resulted in reduced statistical significance. This may have led to greater type I or type II errors; ideally a bigger sample size would have yield more significant and trustworthy results. Furthermore the stable-weight group consisted of mainly overweight individuals, as overweight has too been implicated in executive dysfunction and eating concerns this may have resulted in reduced variance between groups. In order to test this theory additional control groups consisting of stable-weight obese (BMI>30kg/m²) and lean (BMI<25kg/m²) women could aid in our understanding of the differences that are present between these groups compared to reduced-obese women. Importantly the lack of pre weight loss data doesn't allow the observation of changes at the individual level. Data collected before, during and after weight loss would assist in providing greater insight into the behavioural, physiological and cognitive changes that occur on an individual level as this may provide greater insight than when comparing at group level.

3.6 Conclusion

In conclusion the present analysis found that obese-reduced women show differences in their physiological and eating behaviour compared to stable-weight women. These challenges may play an important role in increasing their risk of weight regain following weight loss. Importantly, these differences are still present up to one year after weight loss, indicating that weight regain is still of concern during this time. This finding contributes to the current evidence that reduced-weight individuals experience physiological compensatory responses to weight loss, which in turn can influence their behaviour. Although obese-reduced women displayed no differences in their executive function compared to stable-weight controls, it is unknown whether their executive function may have changed during the weight-loss process itself.

Chapter 4 Intervention Analysis

The Effect of Working Memory Training on Executive Function in Reduced-Obese Women: Implications for Long-term Weight-Loss Maintenance

4.1 Introduction

As detailed in Chapter 1, a major concern in the battle against obesity is that weight-loss maintenance is often unsuccessful; many of those who lose a significant amount of weight will regain most of this weight within a year. The previous chapters explored the challenges associated with weight loss by comparing how reduced-obese women differ from stable-weight women, touching on why these differences may increase their risk of weight regain. As executive function plays an important role in maintaining weight and overcoming these challenges, improving executive function through training may aid in weight-loss maintenance.

One way to potentially improve executive function is through working memory training (WMT). It has been suggested that WM is the largest component of executive function, and that it's processes underly the other components of executive function (Baddeley, 1992). As executive function has been implicated in weight maintenance, it is expected that WM too plays a similar role. Reduced WM capacity has shown associations with overweight and obesity (Y. Yang et al., 2018), while higher WM capacity has been shown to be a predictor of successful weight loss (Hege et al., 2013; Meule, 2016). The logic behind WMT is that if WM can be improved through training, it should in turn improve the components that are interlinked with WM. WMT has therefore emerged as a potential means to improve executive function, thereby improving self-control and discipline in those suffering from impulse driven behaviour.

WMT typically involves the use of adaptive WM tasks, in which the task becomes progressively more difficult as the individual improves over time. Many studies have found this type of training to produce improvements in WM capacity (Klingberg, 2010; Melby-Lervåg & Hulme, 2013). Yet evidence remains controversial on whether these improvements in WM capacity are able to transfer to behaviour. For instance, Houben and colleagues (2016) examined whether WMT would improve self-regulation in overweight participants. The authors found that while all participants who received WMT showed improvements in their WM, only those that were initially reported as highly restrained eaters saw an improvement in their food intake. These findings indicate that transfer of WMT to behaviour may depend on the mindset of the participants. Strengthening WM capacity therefore may be of little use

if there is a lack of motivation to change ones behaviour or a lack of knowledge on what changes need to be made (Hofmann et al., 2012). It is then hypothesised that WMT will only produce an effect if (1) the WMT results in an improvement in WM capacity as well as (2) participants are actively motivated to change their behaviour.

The current study examined this possibility by focusing on women who had already lost a significant amount of weight and were motivated to maintain their weight. In this regard they already had the underlying motivation and knowledge on what lifestyle changes need to be enforced in order to maintain a healthy lifestyle. Having reached the weight-maintenance phase, we examined whether WMT could be used as an aid in weight maintenance following significant weight loss, by incorporating a 6-week WMT intervention into the lives of these recently reduced-obese women. To our knowledge an investigation such as this has not been conducted previously. The hypothesis was that the WMT would improve their WM and executive function thereby improving their self-control and restraint, allowing them to better control their food intake and show greater discipline when it comes to food choices. This would result in greater likelihood of remaining weight stable in the long term.

4.2 Aims and Objectives

This study follows a one-group pre- and post-intervention test, quasi-experimental design. The main aim of this analysis was to determine the effect of a 6-week WMT intervention on cognition, behaviour and physiology in reduced-obese women. The objectives were (1) to determine whether WMT improved WM capacity in reduced-obese women, and whether this was retained in the long term, and (2) whether this in turn affected behaviour and the physiology of reduced-obese women.

4.3 Methods

4.3.1 Participants

Participant recruitment and criteria are described in chapter 2. Nineteen reduced-obese women between the ages of 25 and 45 years (M= 35.6 ± 5.7 years) were chosen for the full intervention analysis (Fig 5.1). All 19 participants completed the full intervention procedures, with no dropouts occurring between baseline testing and post-intervention testing. Only 11 participants completed the 6 month follow up, of the 8 that did not, 2 were unresponsive to communication and 6 missed the 6 month time frame due to unforeseen circumstances.

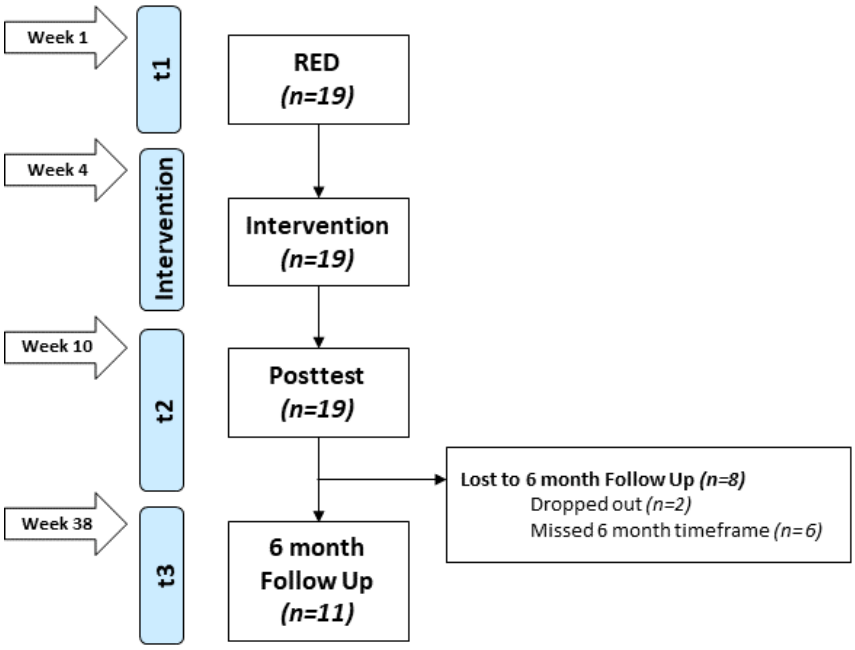


Fig 4.1: Flowchart indicating participant numbers at each point of the intervention. t1: Baseline; t2: Post intervention; t3: 6-month follow-up.

4.3.2 Measures

Measures used in this analysis were those measures that were repeated at post intervention and the follow up. This included anthropometric measures, BIA, executive function tests (BRIEF-A, n-back, DS), resting metabolic rate, appetite measures, and questionnaires (EDE-Q, EEQ, Self-control scale, self-efficacy, WEL and BDI). Full description of measures and experimental design, including the intervention, are described in Chapter 2 (see sections 2.1; 2.2; 2.3; 2.4)

4.3.3 Statistical Analysis

All analyses were conducted using IBM SPSS version 26 for Windows (IBM Corp, Armonk, NY). All variables were tested for normality using the Shapiro-Wilk test. For comparisons between baseline (t1) and post intervention (t2) the paired-t test was used for parametric data, while the Wilcoxon signed-rank test was used for non-parametric data. For measures over time (t1, t2, t3), only the follow up group data was used (n=11) for the three time points, repeated ANOVA was used for parametric data, while Friedman test was used for non-parametric data. Statistical significance was accepted at $p < 0.05$.

4.4 Results

4.4.1 Participant Characteristics

All 19 reduced-obese women completed the WMT intervention. Of this sample the highest level of education was as follows: 5 had a matric certificate, 4 completed a diploma qualification, 3 completed an undergraduate degree and 7 had completed a postgraduate degree. There was equal proportion of ethnicities with 5 of African descent, 6 of mixed race and 8 of Caucasian descent.

Participants had a mean BMI in the range of overweight (27.7 ±3.1 kg/m²), after having lost 21.1 ± 11.1% of their body weight from their highest adult weight. Most of this weight loss occurred in the 6 months and 12 months before recruitment (9.7 ± 8.2% and 17.2 ± 8.7% respectively).

The total duration between Visit 1 and Visit 5 was approximately 73.6 ± 6.3 days, with the intervention running over approximately 39.1 ± 1.5 days. On average participants completed 23.9 ± 0.6 WMT sessions, with only one participant completing 23 sessions and another 22 sessions. Highest levels achieved during the intervention ranged between level 3 to level 8 (M= 5 ± 1.6).

4.4.2 Anthropometric Measures

Table 4.1: Participant anthropometric measures displayed per time point (mean values ± standard deviations)

	t1 *(n= 19)*	t2 *(n= 19)*	t3 *(n= 11)*	t1*t2 *(n=19)*		Repeated *(n= 11)*	
				t	p-value	F	p-value
BMI (kg/m²)	**27.7** ± 3.1	**27.8** ± 3.2	**28.8** ± 1.1	-1.218	0.239	2.472	0.110
Waist (cm)	**83.7** ± 9.4	**84.4** ± 9.4	**85.6** ± 11.9	-1.159	0.261	2.064	0.153
WHtR	**0.5** ± 0.1	**0.5** ± 0.1	**0.5** ± 0.0	-1.147	0.266	2.052	0.155
BF (%)	**33.1** ± 6.3	**33.8** ± 6.6	**35.9** ± 1.9*	-1.490	0.153	7.557	0.004

Measures taken at baseline (t1), post intervention (t2) and six-month follow-up (t3). BMI: Body mass index; WHtR: Waist-to-height ratio; BF: Body fat. * p< 0.05 significantly different from other time points.

There was no significant change between baseline and post intervention in any of the anthropometric measures (Table 4.1). While there was no significant change over time for BMI, waist circumference or WHtR, there was a significant change in body fat over time ($F(2,20)= 7.557$, $p= 0.004$). Bonferroni correction revealed that for the follow-up group body fat did not differ significantly between baseline and post intervention ($p= 1.000$). However, by the 6 month follow-up, body fat had increased to 35.9 ± 1.9%, which was significantly higher than baseline (t1: 33.1 ± 6.3%, $p = 0.029$) and post intervention (t3: 33.8 ± 1.9%, $p= 0.038$).

4.4.3 Executive Function and Working Memory

N-Back

At baseline, total n-back accuracy was within the upper limit (t1: 71.2 ± 15.1%). There was no significant improvement seen at post intervention (t2: 74.2 ± 10.6 %; t(18)= -0.957, p= 0.351) or over time (t3: 75.3 ± 6.3%; F(2,20)= 1.986, p= 0.163). There was no significant change in latency at post intervention (t1: 684(592-784) ms; t2: 617(538-760) ms; z= -1.449, p= 0.147), or over time (t3: 625 (579-676) ms; $\chi^2(2)=2.360$, p= 0.307).

Digit Span

There was no significant change in most fDS measures at post intervention or over time (Table 4.2), with the exception of fML. There was a significant increase in fML between baseline and post intervention (z= -2.226, p= 0.026), however this was lost by the 6 month follow-up, resulting in no significant effect of time for the follow-up group ($\chi^2(2)= 2.55$, p= 0.280).

There was a significant improvement in all bDS measures post intervention (Table 4.2). Furthermore, there was a significant effect of time on bTE_ML ($\chi^2(2)= 14.25$, p= 0.001), bTE_TT ($\chi^2(2)= 10.17$, p= 0.006) and bMS ($\chi^2(2)= 11.46$, p= 0.003). Post-hoc analysis with Wilcoxon signed rank test was conducted to show that follow-up scores were significantly higher than baseline scores in bTE_ML (z= -2.845, p= 0.004), bTE_TT (z= -2.687, p= 0.007), bML (z= -2.111, p= 0.035) and bMS (z= -2.845, p= 0.004). There was no significant change in bDS scores between post-intervention and follow-up.

Table 4.2: Digit span measures displayed per time point (Median values (IQR))

	t1 *(n= 19)*	t2 *(n= 19)*	t3 ***(n= 11)***	t1*t2 *(n= 19)*		Repeated ***(n= 11)***	
				z	p-value	χ^2	p-value
Forward Digit Span							
fTE_ML	**6** (6-7)	**7** (6-7)	**7** (6-7)	-1.387	0.166	2.00	0.368
fTE_TT	**5** (4-6)	**5** (4-6)	**5** (4-7)	-0.792	0.428	0.69	0.710
fML	**7** (6-8)	**7** (7-8)	**7** (6-7)	-2.226	0.026	2.55	0.280
fMS	**6.7** (5.6-7.1)	**6.9** (6-7.5)	**6.3** (6.1-7.5)	-1.087	0.277	3.48	0.176
Backward Digit Span							
bTE_ML	**5** (4-6)	**6** (5-8)	**6** (5-8)	-2.536	0.011	14.25	0.001
bTE_TT	**4** (4-6)	**6** (4-7)	**6** (4-8)	-2.535	0.011	10.17	0.006
bML	**6** (5-7)	**7** (6-9)	**6** (6-8)	-2.658	0.008	4.20	0.122
bMS	**5.9** (4.9-6.9)	**6.3** (5.5-8.2)	**5.8** (5.5-7.4)	-2.938	0.003	11.46	0.003

Digit span measures at baseline (t1), post intervention (t2) and six-month follow-up (t3). t1*t2: Wilcoxon signed rank test used to evaluate differences between baseline and post intervention; Repeated: Friedman's test used to evaluate effect of time over all three time points for the subset of 11 participants.

TE_ML: two error max length; TE_TT: two error total trials; ML: max length; MS: mean span. Error bars represent interquartile range. Significance displayed for post-intervention measures.

BRIEF-A

There was no significant change between baseline and post intervention in any of the BRIEF-A summary scale scores (Table 4.3) or subscale scores (See supplementary S4 for full descriptive), although the MI did appear to increase over time ($x^2(2)=5.060$, p= 0.080). Furthermore, no improvement was seen in the WM subscale post intervention (z= -0.246, p= 0.806) or overtime ($x^2(2)=2.39$, p= 0.303). Majority of the subscales did not see an effect of time, with the exception of the Task monitor subscale, ($x^2(2)=8.267$, p= 0.016). Post-hoc analysis with Wilcoxon signed rank test was conducted to show that the greatest difference in Task monitor scores appeared between baseline and the 6 month follow-up (t1: 51 (42-65) vs t3: 61 (46-65); z= -2.371; p= 0.057).

Table 4.3: BRIEF-A Summary t-scores displayed per time point (Median Values (IQR))

	t1 *(n= 19)*	t2 *(n= 19)*	t3 ***(n= 11)***	t1*t2 *(n= 19)*		Repeated ***(n= 11)***	
				z	p-value	χ^2	p-value
BRI	**54** (50-56)	**51** (47-65)	**52** (48-61)	-0.065	0.948	2.39	0.303
MI	**52** (44-61)	**54** (44-65)	**59** (54-61)	-0.728	0.466	5.06	0.080
GEC	**53** (46-63)	**51** (46-68)	**57** (46-60)	-0.19	0.849	0.33	0.850

Measures taken at baseline (t1), post intervention (t2) and 6-month follow-up (t3). t1*t2: Wilcoxon signed rank test used to evaluate differences between baseline and post intervention; Repeated: Friedman test for repeated measures across all three time points.

BRI: Behaviour regulation Index; MI: Metacognition index; GEC: Global executive composite.

4.4.4 Measures of Energy Metabolism and Appetite

Energy Metabolism

There was no significant change in fasting measures of energy metabolism between baseline and post intervention (RER: t(18)= 0.475, p= 0.641; REE (kcal/kg/day): t(18)= -0.530, p= 0.602; REE (kcal/kg FFM/day): t(18)= -0.936, p= 0.363) or over time (RER: F(2,20)= 0.711, p= 0.503; REE (kcal/kg/day): F(2,20)= 1.341, p= 0.284; REE (kcal/kg FFM/day): F(2,20)= 2.209, p= 0.136). There was no significant change in the thermic effect of feeding (TEF) post intervention (t1: 13.3±5.3% vs t2: 12.7±6.5%, t(18)= 0.370, p= 0.716).

Glucoregulatory response and appetite

There was no significant change in most blood measures between baseline and post intervention, this included fasting glucose (t(18)= -0.520, p= 0.609), fasting insulin (t(18)= -1.220, p= 0.238), HOMA-IR (t(17)= -0.981, p= 0.340), 120 min post-prandial glucose (t(17)= 1.925, p= 0.071) and 120 min post-prandial insulin (t(18)= 1.017, p= 0.323), however, there was a significant increase in HbA1c at post intervention (t1: 34.4 ± 3.6 mmol/mol vs t2: 35.6 ± 4 mmol/mol; t(18)= -2.302, p= 0.033).

In terms of subjective appetite, there was a significant increase post intervention in fasting hunger and desire to eat (Hunger: t1: 18 (3-53) vs t2: 52 (15-78); z=-2.853, p= 0.004)(Desire: t1: 27 (10-54) vs t2: 50 (7-77); z= -2.344, p= 0.019). Desire to eat was also shown to be significantly higher immediately following ingestion of the meal (t1: 0 (0-2) vs t2: 2 (0-6); z= -2.805, p= 0.005). There was no difference in hunger, satiety or desire to eat at 60 min, 120 min or 180 min postprandial.

4.4.5 Measures of Eating Behaviour and Food-related thoughts

There was a significant decrease in the total score of the EDE-Q between baseline and post intervention (t1: 2.6 (1-3.2) vs t2: 2.3 (1-2.8); z= -1.972, p= 0.049) (Fig 4.2). Within the factors, eating restraint (z= -1.767, p= 0.077) and shape concern (z= -1.862, p= 0.063) saw the greatest reduction post intervention. There was no significant change in emotional eating post intervention (t(18)= 0.431, p= 0.627) or over time (F(2,20)= 0.160, p= 0.853) (See supplementary S5 for full descriptive of EDE-Q and EEQ).

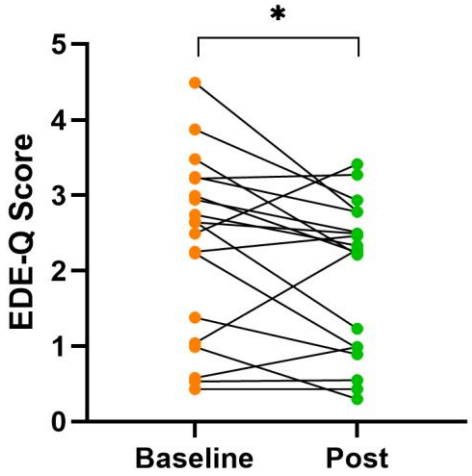


Fig 4.2: Total score for self-reported eating-disordered behaviour displayed individually, as measured by the Eating Disorder and Examination Questionnaire (EDEQ). Time points include Baseline and Post intervention. Dots represent individual data points .* p < 0.05

4.4.6 Measures of Self-control, Self-efficacy and Depression

There was no significant difference post intervention or over time on measures of self-control, weight efficacy, self-efficacy or depression (See supplementary S6 for full descriptive).

4.5 Discussion

The aim of this chapter was to observe the immediate and long-term effects of a 6-week WMT intervention on executive function and behaviour in reduced-obese women. The training resulted in significant training effects on WM capacity, with improvements seen in non-trained tasks that were still retained at the 6 month follow-up. While no change was observed in self-reported cognitive abilities and most behaviours, there was a reduction in self-reported eating-disordered behaviour. On average, participants still experienced a gain in body fat in the long term. It is important to note, however, that without a control group it is difficult to say whether training had no effect on weight or

behaviour or whether there was actually a maintenance effect which went unseen without a control group.

In the current study WMT resulted in a significant improvement in non-trained tasks, which is in line with previous studies (as reviewed by Klingberg, 2010). While there was only a slight improvement in one forward recall measure, maximum length forward recall, all four measures of the backward recall showed improvement. The bDS is a validated measure of WM, while the fDS is a measure of attention and short-term memory and therefore does not in itself measure WM (Baddeley, 1992). While the improvement on the fDS therefore is likely to indicate improved attention, the improvement seen across the bDS is an indication that there may have been an overall improvement in WM capacity. Importantly, the improvement in bDS was likely not a learning effect due to improvement between baseline and post intervention, as the improvement observed in the more difficult bDS task far outweighed any improvement observed in the easier fDS task. While these effects were mostly retained after 6 months of no training, which means that they were maintained over a long-term period, there was an indication that they could be on the decline. As with Dassen and colleagues (2018) who experienced diminished training effects at 6 months, it is suggested that 'top-up' sessions are needed in order to maintain these improvements after 6 months. Interestingly, there was a lack of significant improvement on the trained n-back test itself, though this may have been the result of a "ceiling effect". The in-lab n-back test, used as a measure of WM at each timepoint, consisted of alternating 0-back to 3-back tasks, whereas the n-back training became consistently more difficult overtime and was only censored at 8-back. As baseline abilities were already within the upper limit for the in-lab test it is unsurprising test scores would remain at a similarly high level, especially as training went beyond the difficulty of the in-lab n-back test. Another possibility was the tediousness of the in-lab n-back test itself. As observed by the researcher, many of the participants reported discontent at the length of time that it took to complete the test, especially after having trained on the same task for the preceding 6-weeks. This discontent may have resulted in diminished effort when completing the test at post intervention and follow-up visits, which may have affected participants accuracy scores. This could have resulted in scores that were within the same range as baseline. This highlights the importance of using testing procedures that are not tedious and boring, instead, potentially incorporating game-like elements into the tests themselves.

Despite the improvement on performance-based measures of executive function, there was no immediate effect of training on self-reported measures of executive function, as measured by the BRIEF-A. One explanation could be that as no change was observed in subjective ratings of executive function, it would appear that the WMT was not able to transfer to other areas of executive function.

This is line with other studies that have been unable to demonstrate transfer of WMT to other areas of cognitive function (Melby-Lervåg & Hulme, 2013; Shipstead et al., 2012). Yet, many studies have found WMT to transfer to other areas of cognitive function (Jaeggi et al., 2008; Klingberg, 2010; Morrison & Chein, 2011; Spencer-Smith & Klingberg, 2015). Alternatively it could be that the subjective measure for executive function does not accurately assess one's ability to perform cognitive tasks. Evidence suggests performance-based and subjective measures for executive function assess two different underlying processes of cognitive function, being that one measures optimal performance while the other measures typical performance (Toplak et al., 2013). While executive function may have been improved by the WMT, it may be that participants continued to perform everyday tasks at typical performance. Alternatively, Shwartz and colleagues (2020) found that the BRIEF-A itself, with the exception of the Task Monitor subscale, does not measure executive function but rather the responses are associated with generalised distress and response bias. In the study the Task Monitor subscale was the only scale to show a positive relationship with executive function performance. While the current study did not show an improvement in the Task Monitor subscale immediately post intervention, there was a significant improvement at the 6 month follow up. This could corroborate the improvement in those individuals WM capacity and highlight the efficacy of the WMT. These contradictory findings between objective and subjective measures of executive function are an important acknowledgement that may not measure the same construct and thereby cannot be used interchangeably.

As no change was observed in subjective executive function, this may account for why no training effect was seen in most measures of behaviour expected to be controlled by executive function, such as self-control, self-efficacy or emotional eating. Without a change in the implementation of executive function in daily life, there cannot be a change in the behaviour expected to be controlled by executive function. Although most behaviour saw no change, there was a decrease in self-reported eating-disordered behaviour, with shape concern and dietary restraint declining post intervention. While dietary restraint is an important component in long-term weight maintenance (Vogels et al., 2005), studies show that self-reported dietary restraint may not reflect actual restriction in food intake, but rather reflect eating-related guilt and concerns (de Witt Huberts et al., 2013; Stice et al., 2010). By improving executive function with WMT, this may have resulted in a decline in the obsessive thoughts related to eating and food. Previous studies have suggested a link between the dieting related preoccupation over food and weight with cognition impairment (Kemps et al., 2005; Kemps & Tiggemann, 2005; Leclerc et al., 2020; Martin et al., 2007). When restricting calories through dieting, for some, there is a huge allocation of mental resources towards dieting-related thoughts, this results

in less mental resources available for other cognitive tasks. It could be that by participants allocating more mental resources towards the WMT, that there was a reduction in mental resources being allocated towards these eating-disordered behaviours. While this is merely a theory and more research is needed to confirm this, it could highlight the importance of cognitive training as a means to divert mental resources away from these negative thoughts and behaviours. It is important to acknowledge that external factors may have played a role in the decrease in eating-disordered behaviour, such as the lack of blinding of participants. Due to the extensive nature of the intervention and the number of testing procedures involved, participants had knowledge that they were taking part in a weight-maintenance study. It is well known that participants who are aware of their group assignment can influence their response to the intervention, with those knowingly receiving treatment having greater expectations and favourable outcomes (Schulz & Grimes, 2002). Having known they were taking part in a weight-maintenance study, participants may have felt more relaxed about their eating and dietary behaviours. Therefore future research, with the addition of controls and blinding of participants, will need to be conducted to determine whether this was the result of the WMT itself or external factors.

Energy metabolism and subsequently appetite were identified as potential confounding factors that could influence eating behaviour and weight change. In order to confirm that any changes observed in behaviour or body fat were due to the WMT and not these physiological factors, metabolic measures were taken at baseline and post intervention. The only change in physiology observed, however, was an increase in fasting hunger and desire to eat, and an increase in HbA1c. While participants did appear to experience greater fasted hunger, a likely explanation is the anticipation of the meal. At baseline participants had limited knowledge of the meal they would be eating until it arrived in lab, so there were no taste or smell sensory triggers. At the post-intervention test, the participants knew the layout of the visit and, having previously eaten the meal, anticipated when it would arrive. Evidence shows that anticipation of a meal causes a rise in hunger hormones (Frecka & Mattes, 2008), which explains the increase in hunger seen at the post-intervention test. Although HbA1c saw a slight increase post intervention, the lack of change in glucose and insulin offered no explanation for this change, it was deemed to be possibly due to external factors.

It is important to note that there were limitations to this study which may influence its reliability. The most prevalent limitation was that it did not include a no-treatment control group, which introduces threats towards internal validity. Without a control we need to interpret the results with caution and cannot accurately conclude that the increase in WM capacity and decrease in eating-disordered behaviour was as a result of the WMT itself. A no-treatment reduced-obese control group would aid

in our understanding of the effects that the WMT may have produced. As little change was observed in behaviour and body mass, a no-treatment control group would also confirm whether a maintenance effect occurred due to the WMT. Another limitation was the small sample size at the 6-month follow-up. With only 58% of participants completing the follow up, the long-term effects of the WMT may not be an accurate reflection of the full sample. A final limitation to this study was the inability to observe the training itself and thereby the lack of control over the environment in which training occurred. Participants were advised that training should have been practiced in a quiet environment with little distractions, preferably when participants were feeling most motivated and focused. However, by allowing training to occur in their home environments there was no control over the setting, which introduces the likelihood that distractions could have influenced the results of the training. Surveillance over training sessions and a more consistent approach to training may have improved the training results, resulting in greater WM improvements. Future research should therefore address these issues.

4.6 Conclusion

In conclusion, this investigation found that a 6-week WMT intervention resulted in improvement in non-trained WM tasks in reduced-obese women, which could indicate an increase in WM capacity. These improvements were maintained after 6 months indicating long-term retention of these skills. The WMT did not appear to have an effect on most behaviours, however, there was a general improvement in eating-disordered behaviour, which may indicate a positive outcome of the training in reducing detrimental dieting-related thoughts. While there was no change in body fat post intervention, there was a general increase in body fat after 6-months. The current findings indicate that the value of WMT as a weight-maintenance intervention remains positive, however, the limitations of the study mean that more research is needed in this area to extend on these findings and accurately demonstrate the value of WMT as a weight-maintenance intervention.

Chapter 5 Methodological Analysis

Comparing Subjective and Performance-based Measures of Executive Function in Reduced-Obese and Stable-weight Women

5.1 Introduction

Executive function is known to play a role in weight management, but the effect of weight loss itself on executive function remains unclear. In order to observe how executive function may change over time it is important to identify the appropriate measure of an individual's executive function abilities. Analysis of executive function can be performed using either performance-based measures (neuropsychological tests) or subjective measures. Performance-based measures involve the individual completing a task, while subjective measures are questionnaires that allow for the individual's rating of their own executive function abilities. While both types of measures claim to assess the executive system as a whole, the extent to which they measure the same underlying construct remains unclear. As discrepancies between these measures may have an important impact on our understanding of how executive function may change with weight loss, and thereby a change in cognitive abilities, it is important to understand how these measures relate to one another.

5.1.1 Subjective Measures of Executive Function

Subjective measures of executive function are questionnaires which allow for the individual's assessment and rating of their ability to carry out or complete tasks in everyday life. The Behaviour Rating Inventory of Executive Function-Adult version (BRIEF-A) is one of the most commonly used subjective measure of executive function (Roth et al., 2005). The questionnaire asks the individual to rate 75 statements of everyday life situations, such as 'I get overwhelmed by large tasks' and 'I talk at the wrong time', with the choice of either 'never', 'sometimes' or 'often'. Scores from the answers are compiled into nine subscales, which each represent different components of executive function. These nine subscales are further compiled into two summary index scales and the global summary scale. The four subscales: Inhibit, Shift, Emotional Control, and Self-Monitor, produced the summary scale 'the Behavioural Regulation Index' (BRI). The BRI is made up of the subscales that are involved in maintaining control of ones behaviour and emotional response, which reflects the self-regulation aspect of executive function. The five subscales: Initiate, Working Memory, Plan/Organize, Task Monitor, and Organization of Materials, produce the summary scale 'the Metacognition Index' (MI). The MI is made up of subscales that are involved in initiating activity, sustaining attention, and solving

problems through planning and organization. Together the two index scales produce a Global Executive Composite (GEC) score, which is the summary scale reflecting the individuals level of executive dysfunction, with higher scores indicative of greater executive dysfunction.

The BRIEF-A has demonstrated evidence of reliability and validity as a measure of executive function in adult samples (Roth et al., 2005), it has also been shown to be sensitive to disorders associated with executive dysfunction (Rabin et al., 2006). For instance, studies have shown those suffering from SUD and those with eating disorders score notably higher on the questionnaire compared to normal samples (Ciszewski et al., 2014; Hadjiefthyvoulou et al., 2012; Hagen et al., 2016; Rouel et al., 2016). Due to the ease of the questionnaire and its ecological validity it is a potentially valuable diagnostic tool for executive dysfunction across various settings.

5.1.2 Performance-Based Measures of Executive Function

Performance-based measures of executive function require the completion of a task within a given timeframe. These measures usually assess the individuals' response time and accuracy. The tasks are often performed in a controlled environment with minimal distractions and with guidance from an investigator. The n-back task and digit-span task (DS) are two performance-based tasks of working memory (WM), which is one of the largest components of executive function (Diamond, 2013; Miyake et al., 2000). In addition to the WM component, both tasks require selective and sustained attention, which means that they can also be used as measures of executive function (Diamond, 2013). The DS involves recalling numbers in either forward recall (fDS) or backward recall (bDS). The fDS is a measure of attention and short-term memory, while the bDS is a validated measure of WM as it requires the retention and manipulation of a number sequence (Baddeley, 1992). The n-back task is a common measure of WM used in neuro-imaging research, and the task has been found to activate the neutral substrates associated with WM processes (Braver et al., 1997; Manoach et al., 1997).

5.1.3 Association between Subjective and Performance-based Measures of Executive Function in the Literature

Evidence for association between subjective and performance-based measures of executive function remains controversial. Various studies have not found evidence for association between these measures in healthy participants (Davids et al., 2016; Jacola et al., 2014) or those suffering from various neuropsychological disorders (Gelonch et al., 2016; Goverover et al., 2005; Koerts et al., 2011; Niendam et al., 2007; Vlagsma et al., 2017). However, weak correlations between these measures have been found in those suffering from autism (Davids et al., 2016), bipolar disorder (Demant et al., 2015), traumatic brain injury (Bennett et al., 2005), and troubled youth (Mcauley et al., 2010; Nordvall

et al., 2017). Only a few studies have compared n-back task accuracy to measures of the BRIEF-A (Gelonch et al., 2016; Jacola et al., 2014; Mcauley et al., 2010; Nordvall et al., 2017), although results remain controversial with some studies finding either negative correlations (Gelonch et al., 2016; Nordvall et al., 2017), positive correlations (Mcauley et al., 2010) or no correlation (Jacola et al., 2014). The review by Toplak and colleagues (2013) suggests that these discrepancies show little evidence for association between performance-based measures and subjective measures of executive function, as one assesses the completion of a structured task while the other assesses the numerous unstructured and unguided tasks of everyday life.

As evidence remains controversial on the association between subjective and performance-based measures of executive function, it is important to identify whether these associations exist across various populations. By understanding how these measures relate to one another, our understanding of an individual's actual executive function abilities, and how they may be able to improve it, will enhance.

5.2 Aims and Objectives

No study to date has explored the associations between performance-based and subjective measures of executive function in a sample of majority reduced-obese women. The aim of this chapter was to explore the relationship between the subjective measure of executive function, BRIEF-A, and the performance-based measures of executive function, n-back and DS, in a sample of majority reduced-obese women. The specific objectives were (1) to determine whether there is an association between the n-back task, the DS task (fDS, bDS) and the BRIEF-A questionnaire; and (2) to understand the relationship that may exist between them.

5.3 Methods

5.3.1 Participants

Participants (n=29) were described in chapter 3.3.1, data presented in the current analysis consisted of baseline measures. Full description of criteria and recruitment are described in chapter 2 (see section 2.1). Participants had a mean age of 35.5 ± 5.8 years, a BMI of 27.5 ± 3.2 kg/m², WHtR of 0.5 ± 0.1, and body fat of 32.9 ±6.4 %. Mean total weight loss was 16.8 ± 12.1 %, however, 6 participants had no weight loss history.

5.3.2 Measures

Correlation analyses were conducted between performance-based measures of executive function and a subjective measure of executive function to determine if there was any association between them. The performance-based measures used were measures of the n-back task and DS (fDS; bDS). The subjective measure used was the BRIEF-A. Additionally, correlation analyses were conducted between the n-back and DS to determine if they two showed any association. Full description of these executive function measures are described in Chapter 2 (see section 2.3.4).

Multiple linear regression was undertaken to determine whether performance-based measures of executive function could predict the subjective measure, while controlling for variables that may themselves influence subjective executive function. Covariates used in the final regression included: age, percentage weight loss, depression status and eating-disordered behaviour. Percentage weight loss was used as a covariate in order to control for the fact that the sample included women with no weight loss history (n=6). Depression status, determined using the Becks Depression Inventory (BDI), was chosen as a covariate as depression has been shown to be a strong predictor of executive dysfunction (Cserjési et al., 2009; Mohammadnia et al., 2020; Wingo et al., 2013). Additionally, the Eating Disorder Examination Questionnaire (EDE-Q) was included as covariate as not only did the EDE-Q show variability between participants in Chapter 3, but the literature also highlights that the presence of eating-disordered behaviour can be indicative of subjective executive dysfunction, with those suffering from eating disorders scoring poorly on subjective ratings of executive function (Ciszewski et al., 2014; Koven & Senbonmatsu, 2013). Full description of the EDE-Q and BDI are described in Chapter 2 (see section 2.3.2).

5.3.3 Statistical Analysis

Analyses were conducted using IBM SPSS version 26 for Windows (IBM Corp, Armonk, NY) and GraphPad Prism version 8.0.0 for Windows (GraphPad Software, San Diego, California USA; www.graphpad.com). All variables were tested for normality using the Shapiro-Wilk test. Correlations were conducted using Spearman-rho correlations for non-parametric data, as some of the variables revealed a non-parametric distribution. Associations between performance-based measures and subjective measures were further analysed using linear regression analysis. Correlations and analyses were conducted first with only the reduced-obese participants and then with the addition of stable-weight participants. As the addition of stable-weight participants served only to strengthen the observed associations, it was decided to include these findings in the final results. Statistical significance was accepted at $p < 0.05$.

5.4 Results

5.4.1 Correlations

N-back and DS

Correlation analyses were conducted between the n-back task (accuracy and latency) and measures of the fDS and bDS (Fig 5.1).

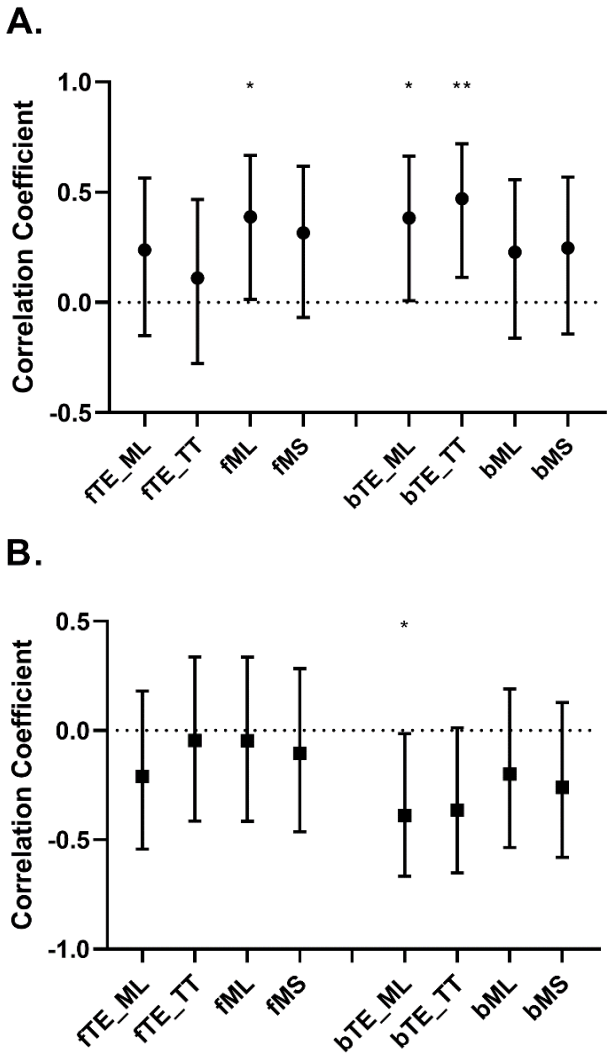


Fig 5.1: Correlation between different measures of fDS and bDS with (A) N-back accuracy and (B) N-back latency. The preceding lower case 'f' denotes forward digit span measures, the preceding lower case 'b' denotes backward digit span measures. Points represent the r value as determined by Spearmans-rho; error bars represent 95% confidence interval. TE_ML: two error max length; TE_TT: two error total trials; ML: max length; MS: mean span.

*** p < 0.05 ** p < 0.01 (2-tailed)**

N-back accuracy showed a significant positive association with one measures of fDS, fML (r=0.389, p= 0.037). N-back accuracy was also positively associated with two measures of the bDS, bTE_ML (r=

0.383, p= 0.040) and bTE_TT (r= 0.471, p= 0.010), such that higher n-back accuracy was associated with longer forward-span maximum length and a less likelihood to make two consecutive errors in the early stages of bDS.

N-back latency did not show any associations with fDS measures. Latency did, however, show a negative correlation with bTE_ML (r= -0.389, p= 0.037). This meant that longer reaction time on the n-back task was associated with less precision at the start of the bDS; such that those who responded slowly during the n-back were more likely to make two consecutive errors in the early stages of the bDS.

N-back and BRIEF-A

Correlation analyses were conducted between n-back measures (accuracy and latency) and BRIEF-A (subscales and summary scales) (Fig 5.2). N-back accuracy showed a significant positive correlation with the inhibit (r= 0.550, p= 0.002) and emotional control subscales (r= 0.473, p= 0.010); resulting in a significant positive correlation with the BRI summary scale (r= 0.545, p= 0.002) and GEC summary scale (r= 0.368, p= 0.050). This means that greater accuracy on the n-back task was associated with higher scores on the two subscales of the BRI and the BRI and GEC summary scales themselves.

Latency showed a significant positive correlation with the plan subscale (r= 0.506, p= 0.005). The plan subscale is a component of the MI summary scale, which resulted in latency showing a positive correlation with the MI summary scale (r= 0.398, p= 0.033). This means that slower response time on the n-back task was associated with a higher score on the plan subscale and MI summary scale. Neither n-back accuracy nor n-back latency showed correlation with the WM subscale (r= 0.118, p= 0.541 and r= 0.298, p= 0.116).

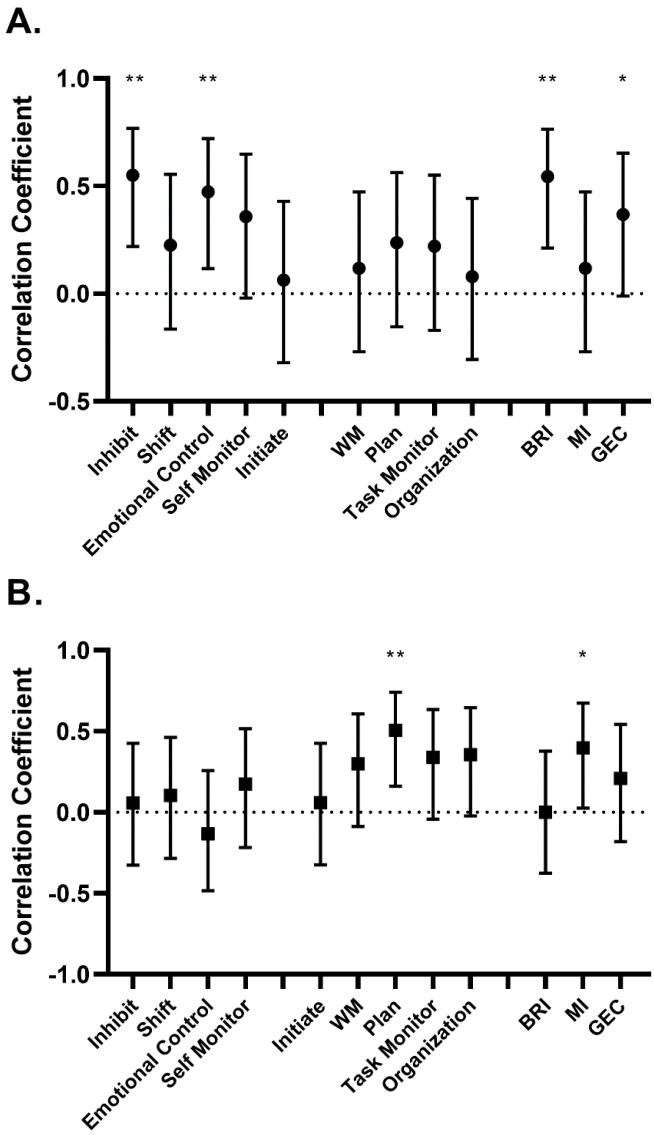


Fig 5.2: Correlation between different scales of the BRIEF-A and (A) N-back accuracy and (B) N-back latency. First grouping (inhibit; shift; emotional control; self-monitor) is made up of the subscales representing the BRI scale; second grouping (initiate; WM; plan; task monitor; organization) is made up of the subscales representing the MI scale; third grouping (BRI; MI; GEC) is made up of the summary scales. Points represent the r value as determined by Spearmans-rho; error bars represent 95% confidence interval. BRI: Behaviour Regulation Index; MI: Metacognition index; GEC: Global Executive Composite.

*** p < 0.05, **p < 0.01 (2-tailed).**

BRIEF-A and DS

Correlation analysis was conducted between BRIEF-A (subscales and summary scales) and measures of the fDS and bDS (See supplementary material S8 for full correlations). There were no significant associations between any of the scales of the BRIEF-A and either fDS or bDS measures.

5.4.2 Regression Analysis

Linear regression was undertaken to determine the associations between subjective and performance-based measures of executive function in reduced-obese women. The BRIEF-A summary indexes, BRI and MI, were the two main dependent variables as they each encompass the two components of the BRIEF-A. The n-back was chosen as the predictor variable for BRI and MI as it showed correlations with the BRIEF-A, while DS did not show any correlation with BRIEF-A. N-back accuracy was chosen as the predictor variable for the BRI as it showed significant correlations with two subscales associated with the BRI (Inhibit and Emotional Control) and the BRI itself. N-back latency was chosen as the predictor variable for the MI as it showed significant correlations with the subscale associated with the MI (Plan) and the MI itself. Regression models were first run with the covariates and then with the predictor variable. The regression model was then run again with the removal of non-significant covariates.

Behaviour Regulation Index

To examine whether n-back accuracy could predict the BRI, BRI was regressed on the independent variable while controlling for age, weight loss, depression and eating-disordered behaviour (Table 5.1). The first model explained 52% of the variance in BRI, with depression being a significant predictor of the BRI. After accounting for covariates, the overall second model was significant ($F(5,23)=11.244$, $p< 0.001$) and explained 65% of the variance in the BRI, with accuracy accounting for 13% ($\Delta R^2= 0.128$).

As age, percentage weight loss and EDE-Q were not predictors of BRI, the model was run again without these covariates to see if BDI and accuracy could still predict the BRI (Table 5.2). BDI by itself explained 55% of the variance in the BRI. With the inclusion of accuracy the model was still significant ($F(3,25)= 20.320$, $p< 0.000$) and explained 67% of the variance in the BRI. The removal of the covariates therefore resulted in very little change to the model.

Table 5.1: Multiple linear regression analysis predicting BRI scores

	Predictors	B	SEB	β	t	p	R	adj. R^2
Model 1						0.000	0.766	0.519
	Age	0.035	0.228	0.022	0.154	0.879		
	% Wt Lost	-0.020	0.106	-0.026	-0.193	0.849		
	BDI	0.537	0.107	0.712	5.029	0.000		
	EDE-Q	1.149	0.986	0.160	1.165	0.255		
Model 2						0.000	0.842	0.647
	Age	0.001	0.196	0.001	0.005	0.996		
	% Wt Lost	-0.018	0.091	-0.023	-0.195	0.847		
	BDI	0.501	0.092	0.664	5.433	0.000		
	EDE-Q	1.008	0.846	0.140	1.191	0.246		
	Accuracy	0.217	0.070	0.355	3.112	0.005		

BDI: Becks Depression Inventory; Accuracy: N-back accuracy; EDE-Q: Eating Disorder Examination Questionnaire; B: Unstandardised beta coefficient; SEB: Standard error coefficient; β: Standard coefficient.

Table 5.2: Multiple linear regression analysis predicting BRI scores after removal of non-significant covariates

	Predictors	B	SEB	β	t	p	R	adj. R^2
Model 1						0.000	0.751	0.548
	BDI	0.567	0.096	0.751	5.910	0.000		
Model 2						0.000	0.832	0.668
	BDI	0.522	0.083	0.692	6.267	0.000		
	Accuracy	0.221	0.067	0.362	3.279	0.003		

BDI: Becks Depression Inventory; Accuracy: N-back accuracy; EDE-Q: Eating Disorder Examination Questionnaire; B: Unstandardised beta coefficient; SEB: Standard error coefficient; β: Standard coefficient.

Metacognition Index

To examine whether n-back latency could predict the MI, MI was regressed on the independent variable while controlling for age, weight loss, depression and eating-disordered behaviour (Table 5.3). The first model explained 49% of the variance in MI, with depression being a significant predictor of

the MI. After accounting for covariates, the overall second model was significant ($F(5,23)=10.497$, $p< 0.001$) and explained 63% of the variance in MI, with latency accounting for 14% ($\Delta R^2= 0.141$).

Table 5.3: Multiple linear regression analysis predicting MI scores

Predictors	B	SEB	β	t	p	R	adj. R^2
Model 1					0.000	0.749	0.488
Age	0.287	0.288	0.144	0.996	0.329		
% Wt Lost	-0.093	0.134	-0.097	-0.693	0.495		
BDI	0.580	0.135	0.629	4.305	0.000		
EDE-Q	1.604	1.245	0.183	1.289	0.210		
Model 2					0.000	0.834	0.629
Age	0.156	0.249	0.078	0.627	0.537		
% Wt Lost	-0.006	0.117	-0.006	-0.047	0.963		
BDI	0.546	0.115	0.592	4.740	0.000		
EDE-Q	2.201	1.076	0.251	2.047	0.052		
Latency	0.034	0.011	0.399	3.186	0.004		

BDI: Becks Depression Inventory; Latency: N-back latency; EDE-Q: Eating Disorder Examination Questionnaire; B: Unstandardised beta coefficient; SEB: Standard error coefficient; β: Standard coefficient.

As age, percentage weight loss and EDE-Q were not significant predictors of MI, the model was run again without these covariates to examine whether depression status and latency were still able to predict the MI score (Table 5.4). BDI by itself explained 49% of the variance in MI. With the inclusion of latency the model was still significant ($F(2,26)= 22.720$, $p< 0.000$) and explained 61% of the variance in MI, again, displaying results very similar to those before the removal of the covariates.

Table 5.4: Multiple linear regression analysis predicting MI scores after removal of non-significant covariates

Predictors	B	SEB	β	t	p	R	adj. R^2
Model 1					0.000	0.714	0.492
BDI	0.659	0.124	0.714	5.299	0.000		
Model 2					0.000	0.798	0.608
BDI	0.618	0.110	0.670	5.616	0.000		
Latency	0.030	0.010	0.358	3.003	0.006		

BDI: Becks Depression Inventory; Latency: N-back latency; EDE-Q: Eating Disorder Examination Questionnaire; B: Unstandardised beta coefficient; SEB: Standard error coefficient; β: Standard coefficient.

5.5 Discussion

The aim of this chapter was to explore the associations between subjective and performance-based measures of executive function in a group of reduced-obese and stable-weight women. The performance-based measures showed good associations to one another, yet, contrary to what was expected, the n-back task showed a significant positive association with the BRIEF-A; such that those who scored poorly on the BRIEF-A performed better on the n-back task. In addition, there was little evidence for association between the DS and BRIEF-A.

An important component of this analysis was first determining if there was a relationship between the two performance-based measures of executive function. While the bDS is a commonly used clinical measure for WM, some suggest that the n-back is not a valid measure of WM (Jaeggi et al., 2010; Miller et al., 2009). The current analysis found a positive association between measures of bDS and n-back accuracy, which is consistent with a number of studies to have found n-back accuracy to positively correlate with bDS in healthy populations (Gevins & Smith, 2000; Jacola et al., 2014; Jaeggi et al., 2010; Roberts & Gibson, 2002). In the backward span task, those with higher accuracy on the n-back task were more likely to reach later trials before making their first two consecutive errors; however, n-back accuracy did not show association with maximum backward recall, which means n-back accuracy was only associated with better performance in the early stages of the bDS task. Yang (2017) suggests that the two trial maximum length (TT-ML) is a true and traditional measure of digit span as the final maximum recall will be based heavily on how quickly it takes before the errors are made. N-back accuracy also showed an association with maximum forward recall, which is likely the

association between the attention component of both measures (Baddeley, 1992; Diamond, 2013). Furthermore, consistent with other findings, n-back latency showed some association with the bDS (Gevins & Smith, 2000; Jacola et al., 2014; Jaeggi et al., 2010), such that faster reaction times on the n-back task were associated with longer list recall on the backward span before making two consecutive errors. These associations add to the current literature which may help to validate the use of the n-back task as a WM measure and training tool.

There was no evidence to indicate a relationship between the bDS and the validated BRIEF-A. Although the bDS is a common measure of WM, and thereby executive function, it showed no associations with the WM subscale on the BRIEF-A. To date only one study has been able to find an association between bDS and the WM subscale of BRIEF-A. The study by Garlinghouse and colleagues (2010) found that in a sample of schizophrenia patients, poor subjective WM (high scores on the WM subscale) was associated with better performance on the bDS, which is contrary to what was expected. The authors suggest that either the two measures are disparate in nature or that these patients were not sufficiently self-aware to accurately perceive their cognitive abilities in everyday life.

Despite the lack of association between DS and BRIEF-A, the current study found the n-back task showed evidence of association with the BRIEF-A. The current analysis found n-back accuracy to show a positive relationship with the Initiate and Emotional control subscales, resulting in a strong positive relationship with the BRI summary scale. The BRI is the summary index involved in maintaining control of ones behaviour and emotional response. In general, high scores on the BRIEF-A indicate a greater degree of executive dysfunction (i.e. higher scores are considered poor), while high accuracy on the n-back indicates better WM performance. This positive association between the measures therefore suggests an inverse relationship, with better accuracy scores associated with poorer BRI scores. In previous studies n-back accuracy has been found to negatively correlate with the BRI subscales of inhibit and shift in fibromyalgia patients (Gelonch et al., 2016) and troubled youth (Nordvall et al., 2017), but there have been opposing results regarding the WM, initiate, organisation of materials and plan subscales. In regards to the MI, previous studies have shown n-back accuracy to negatively correlate with the MI in fibromyalgia patients (Gelonch et al., 2016), but positively correlate with the MI summary scale in ADHD adolescents (Mcauley et al., 2010), while the current study found no association between n-back accuracy and the MI. The n-back task reaction time did, however, show a positive association with the Plan subscale and thereby the MI summary scale. The MI is the summary scale involved in initiating activity and problem solving across a variety of situations. Unsurprising in this regard, faster response time on the n-back task was associated with better (lower) MI scores, indicating better control over initiating responses. This is one of the few studies to have compared n-

back latency to BRIEF-A. Jacola and colleagues (2014) is the only other study to have compared these two measures, however, only the WM subscale was used as the BRIEF-A component in the comparison and was found to have no correlation with n-back latency.

The different association of the n-back accuracy and latency to separate indexes of the BRIEF-A would indicate that each could potentially represent different components of executive function. Interestingly, although the n-back task is used as a measure of WM, neither accuracy nor latency correlated with the WM subscale of the BRIEF-A. Although it's important to note that bDS, a more commonly used measure for WM did not correlate with this subscale either.

Two theories may explain the contradictory and inverse association found between n-back accuracy and the BRIEF-A; either the participants are overly self-critical resulting in exaggerated self-ratings, or the two types of measures are not associated. The creators of the BRIEF-A (Roth et al., 2005) suggest that high scores on the BRIEF-A in opposition to what is seen by others, or in performance, could be a result of an overly critical self-analysis or distress on the individual. This is in line with others who theorise that the discordance between these measures may be due to difficulties with self-perception, self-evaluation and/or emotional distress, common in neurological disorders, which may affect subjective ratings of cognitive abilities (Fuermaier et al., 2015; Garlinghouse et al., 2010; Shwartz et al., 2020; Vlagsma et al., 2017). As our sample contained majority overweight women, of which most were recently reduced-obese, it could be that weight-loss behaviour, such as dieting and eating restraint, may have contributed towards feelings of distress and loss of control (Atlantis & Ball, 2008). For this reason it was decided to control for variables which might influence participants views of themselves, such as eating behaviour and depression. For instance those with eating disorders have been shown to score higher on measures of the BRIEF-A (Ciszewski et al., 2014; Koven & Senbonmatsu, 2013). In the current analysis eating-disordered behaviour appeared to have little predictive power over the BRI summary scale, however, it did appear to offer some influence over the MI summary scale. The study by Koven & Senbonmatsu (2013) found a similar discrepancy between the subjective and performance-based measures of executive function in a sample of orthorexia nervosa (ON) women. The study, which involved a random non-clinical sample of students, found those who scored within the range for orthorexia nervosa (ON) scored significantly higher on measures of the BRIEF-A. ON is a disordered eating behaviour in which the individual is fixated on healthy eating, resulting in a restrictive-diet mindset. Yet, interestingly, the ON sample from the study did not significantly differ from controls in six out of the seven performance-based measures of executive function. This would imply that while their subjective measures label them as possibly having executive dysfunction, their performance-based measures did not, indicating a similar discrepancy in WM methodologies.

Overall, depression status had the greatest predictive power over both summary scales, accounting for half the variance seen in each summary scale. Depression has been found to be associated with executive dysfunction, and has been implicated along with executive dysfunction as a mediating factor in weight gain (Cserjési et al., 2009). For instance in a group of college students, depression status was correlated with BRIEF-A, however, neither BRIEF-A nor depression status were correlated with performance-based measures of executive function (Wingo et al., 2013). It is therefore unsurprising that depression status as measured by the BDI had the greatest predictive power over the BRIEF-A. Yet, despite controlling for these variables, n-back accuracy and latency still held predictive power over the BRIEF-A.

As per the second explanation for the contradictory association found between n-back accuracy and the BRIEF-A, it may just be that the two types of measures represent different types of executive functioning, and therefore cannot be used interchangeably. Correlation between subjective and performance-based measures of executive function appear to differ greatly across studies, implying that they may not be measuring the same construct (as reviewed by Toplak et al., 2013). Yet these two types of measures may still be of importance. Subjective and performance-based measures of executive function together may indicate how well individual are able to utilise their executive function abilities depending on the environment they are in, thereby indicating an individual's optimal performance vs their typical performance (Toplak et al., 2013). Performance-based measures are performed in a structured environment in which the individual is asked to complete a task under a certain time limit; whereas subjective measures are an assessment of how the individual performs in the somewhat unstructured environment of everyday life. In other words, one measures their actual abilities while the other measures how well they utilise their abilities. Performance-based measures therefore are a good indication of actual executive function and together with the subjective measure may indicate whether executive function needs to be strengthened (i.e. with training) or whether more focus needs to be directed towards learning how to utilise executive function in every day life.

Future research may aid in our understanding of these theories by addressing the limitations faced in this study. The major limitation to this analysis was that no measure of executive function was taken before the individuals lost weight, as weight loss is thought to affect executive function (Brinkworth et al., 2009; Clarkson et al., 2011; Green et al., 1997; Hester & Garavan, 2005; Kemps & Tiggemann, 2005; Siervo et al., 2012), his data could add to our understanding of how their abilities may have changed during this time and whether this resulted in the controversial results obtained in this analysis. The small sample size was also a limiting factor as the large confidence intervals would have resulted in a loss of significance, therefore replication is required with a larger sample size. The

analysis could also have been improved with the addition of varied performance-based measures of executive function. Although WM can be used as a proxy of executive function (McCabe et al., 2010), with both n-back and DS used as measures of executive function (Diamond, 2013), it may have been beneficial to include tasks focused on the other two components of executive function, inhibition and cognitive flexibility. The addition of inhibitory tasks, such as the Stroop task (MacLeod, 1991), or cognitive flexibility tasks, such as the Wisconsin Card Sorting Task (Milner, 1963; H. E. Nelson, 1976), may have added greater insight to their performance-based results.

5.6 Conclusion

In conclusion, there was evidence of association between subjective and performance-based measures of executive function in a majority reduced-obese sample of women. While depression played the greatest predictive role in predicting the BRIEF-A summary indexes, the n-back task, a performance-based measure of WM, showed associations with these summary indexes, despite n-back accuracy displaying an inverse relationship with the BRI. This controversial association between the measures add to the uncertainty that they measure the same underlying construct. This analysis highlights the importance of utilising both types of measures in the analysis of executive function as each measure may provide useful information and a complementary understanding of how executive function is being utilised in different environments. Importantly, the n-back task showed associations with the bDS, a validated measure of WM, this finding advocates for the use of the n-back task as a measure and training tool for WM.

Chapter 6 Concluding Remarks

In its investigation in the changes that occur after significant weight loss, the aim was to investigate the behavioural, physiological and cognitive differences between reduced-obese women and stable-weight women. The findings of this study support our understanding of what we know to occur physiologically, however, the cognitive changes still remain uncertain. The study found that reduced-obese women, who had significantly reduce their body mass within the 18 months prior, displayed reduced post-prandial energy metabolism and greater symptoms of eating-disordered behaviour compared to stable-weight women. Importantly, these differences were still present in reduced-obese women who had maintained their weight for at least 6 months after their weight loss. This physiological compensatory response to weight loss and detrimental food-related thoughts may put reduced-weight women at risk for weight regain. This highlights the importance of the weight maintenance phase being included as a component during weight loss initiatives, as long-term weight loss maintenance is often unsuccessful due to these increased risk factors for weight regain. Treatment initiatives should therefore focus on ways to sustain discipline and self-control after weight loss in order to overcome the physiological and psychological compensatory responses to weight loss, which may induce increased appetite and lower metabolism. While there was no observed difference between reduced-obese and stable-weight women in terms of executive function, executive function has been identified as an important component in impulse control and thereby self-control and discipline. Improving executive function in these reduced-obese women could allow them to maintain control over their diet and allow them to overcome cravings. WMT having been identified as a potential way to improve on executive function could be an important stepping stone towards improving weight-loss maintenance outcomes. As an easy to administer treatment, it is therefore important to investigate the effects a WMT intervention may have on reduced-obese individuals and whether it benefits in their ability to maintain their weight in the long term.

In its investigation into the effects of a WMT intervention on reduced-obese women, the aim was to investigate whether WMT could improve on any factors that might lead to better weight maintenance. The findings of this study add to the few studies that have been conducted in this area. WMT was found to improve WM capacity in reduced-obese women, as measured through performance-based (objective) measures of WM. Yet, the ability of improved WM to transfer to other areas of cognition or behaviour remains unclear. No change was observed in the subjective measure of executive function, a self-rated measure of the utilisation of executive function in everyday life. This lack of change in self-rated executive behaviour could explain why no change was observed in self-rated self-

control, self-efficacy, emotional eating or depression. Yet, there was a reduction in eating-disordered behaviour, as measured through a self-rated questionnaire, with a reduction in shape concern and dietary restraint. This could indicate a positive effect of training in reducing obsessive thoughts related to eating and food. While there was still a general gain in body fat over the long term, it is unknown whether the training had no effect on weight maintenance or if the gain in body fat was possibly reduced due to the training. It's important to note that without a control group there was no comparison group in order to corroborate these findings. Additionally, the conflicting findings between the observed improvement in the performance-based measure of executive function compared with no change observed in the subjective measure of executive function, arises the need to determine whether they measure the same construct and to offer an explanation as to why they may differ. The current findings indicate that the value of WMT as a weight-maintenance intervention remains positive, however, the limitations identified in this study, such as the lack of control group and non-blinding of participants, mean that more research is needed in this area to extend on these findings and accurately demonstrate the value of WMT as a weight-maintenance intervention. The analysis offers future research valuable insight and the ability to improve on and correct those concerns in order to fully understand whether or not WMT can aid in weight maintenance.

In its investigation into the relationship between WM methodologies, the aim was to determine the association that exists between subjective and performance-based measures of executive function. The findings of this study are in many ways both contradictory and supported by studies found elsewhere, although it is important to note that no other study has made these comparisons using a sample of majority reduced-obese women. The current analysis found a positive association between the n-back task and the BRIEF-A, with n-back accuracy inversely associated to the BRI of the BRIEF-A and n-back latency positively associated to the MI of the BRIEF-A. Furthermore the n-back task was found to show associations with digit span backwards, a commonly used measure for WM, which helps justify the use of the n-back task as a WM measure. While some studies have found no signs of association between performance-based and subjective measures of executive function, those that have found associations show weak but often supporting associations. The controversial relationship between n-back accuracy and BRIEF-A, may suggests that subjective and objective measures of executive function measure different constructs of executive function. Performance-based measures of executive function measure actual abilities (optimal performance) while subjective measures of executive function measures how well these abilities are utilised in everyday life. This supports the idea that both measures should be utilised in studies involving executive function and identifies why contradictory results may be observed when incorporating both types of measures.

It is important to address the biases and limitations that exist within this study in order to improve upon for future research. The biggest limitation of this study is the threat to internal validity. It is important to note that due to the Covid-19 pandemic of 2020, the current study had to be adapted due to the halt in all research activities which resulted in a reduced sample size. This was mainly observed in the reduced control group in the crossover study and a lack of control group in the intervention analysis. Reduced sample sizes within the crossover analysis mean that differences between groups may have gone unseen and that results need to be interpreted with caution. With no follow up data for controls, the intervention analysis had to follow a within-subject design, which means that the current findings are speculatory and cannot be confirmed to be a result of the WMT, as there is a chance they may be the result of external factors. Due to the limitations introduced in the first two analyses, an additional methodological chapter was included to increase the scientific relevance of this dissertation.

In addition to the reduced sample size, bias may have been introduced into this study due to the unblinding of participants and researchers, and the lack of randomization in the selection of the experimental group. The study was conducted by a single researcher, and due to the nature of the study, participants were aware that the focus of the study was to improve weight maintenance. Additionally the exclusion criteria did not address various behaviour or cognitive problems that could be considered confounders, such as ADHD, anxiety, depression, stress load etc., exclusions for these criteria may well be beneficial in future research.

Recommendations for future studies comparing reduced-obese and stable weight groups includes the addition of pre-weight loss executive function measures. Observation on how executive function may change before weight loss and after weight loss may aid in our understanding of how executive function may change during the weight maintenance phase, or how it can be improved upon. This data would also assist when comparing reduced-obese subjects to stable weight controls, to account for why there may or may not be a difference between groups. Future research on weight-loss maintenance could also consider the other components of executive function, by incorporating them collectively into the intervention. By incorporating different tasks that address each component, such as inhibition tasks or cognitive flexibility tasks, the likely hood of a transfer to behaviour may be improved upon. This incorporation of different tasks is also likely to increase participants motivation and interest as the task no longer becomes repetitive.

In conclusion this study adds to the literature on the effects of WMT, and while the results need to be interpretated with caution the findings of this study add positive insight into the efficacy of WMT in reduced-obese women and offers a substantiated hypothesis for future research.

Chapter 7 References

Allan, J.L., McMinn, D. and Daly, M., 2016. A bidirectional relationship between executive function and health behavior: evidence, implications, and future directions. *Frontiers in neuroscience, 10*, 386.

Allom, V., & Mullan, B. (2014). Individual differences in executive function predict distinct eating behaviours. *Appetite*, *80*, 123–130. https://doi.org/10.1016/j.appet.2014.05.007

Ames, G. E., Heckman, M. G., Diehl, N. N., Grothe, K. B., & Clark, M. M. (2015). Further statistical and clinical validity for the weight efficacy lifestyle questionnaire-short form. *Eating Behaviors*, *18*, 115–119.

Anderson, J. W., & Konz, E. C. (2001). Obesity and disease management: effects of weight loss on comorbid conditions. *Obesity Research*, *9 Suppl 4*(November). https://doi.org/10.1038/oby.2001.138

Anderson, J. W., Konz, E. C., Frederich, R. C., & Wood, C. L. (2001). Long-term weight-loss maintenance : a meta-analysis of US Studies. *Am J Clin Nutri*, *74*, 579–584.

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

Armstrong, T., & Bull, F. (2006). Development of the World Health Organization Global Physical Activity Questionnaire (GPAQ). *Journal of Public Health*, *14*(2), 66–70. https://doi.org/10.1007/s10389-006-0024-x

Atlantis, E., & Ball, K. (2008). Association between weight perception and psychological distress. *International Journal of Obesity*, *32*(4), 715–721. https://doi.org/10.1038/sj.ijo.0803762

Austin, J., & Marks, D. (2009). Hormonal Regulators of Appetite. *International Journal of Pediatric Endocrinology*, *2009*, 1–9. https://doi.org/10.1155/2009/141753

Avena, N. M., Rada, P., & Hoebel, B. G. (2008). Evidence for sugar addiction: Behavioral and neurochemical effects of intermittent, excessive sugar intake. *Neuroscience and Biobehavioral Reviews*, *32*(1), 20–39. https://doi.org/10.1016/j.neubiorev.2007.04.019

Baddeley, A. (1992). Working Memory. *Science*, *255*(5044), 556–55916.

Barry, D., Pietrzak, R. H., & Petry, N. M. (2008). Gender differences in associations between body mass index and DSM-IV mood and anxiety disorders: results from the National Epidemiologic Survey on Alcohol and Related Conditions. *Annals of Epidemiology*, *18*(6), 458–466.

Beck, A. T., Steer, R. A., & Brown, G. (1996). Beck depression inventory–II. *Psychological Assessment*.

Bennett, P. C., Ong, B., & Ponsford, J. (2005). Measuring executive dysfunction in an acute rehabilitation setting: Using the dysexecutive questionnaire (DEX). *Journal of the International Neuropsychological Society*, *11*(4), 376–385. https://doi.org/10.1017/S1355617705050423

Bickel, W. K., Moody, L., & Quisenberry, A. (2014). Computerized working-memory training as a candidate adjunctive treatment for addiction. *Alcohol Research: Current Reviews*, *36*(1), 123–126.

Blond, E., Maitrepierre, C., Normand, S., Sothier, M., Roth, H., Goudable, J., & Laville, M. (2011). A new indirect calorimeter is accurate and reliable for measuring basal energy expenditure, thermic effect of food and substrate oxidation in obese and healthy subjects. *E-SPEN*, *6*(1), e7–e15. https://doi.org/10.1016/j.eclnm.2010.12.001

Braden, A., Flatt, S. W., Boutelle, K. N., Strong, D., Sherwood, N. E., & Rock, C. L. (2016). Emotional eating is associated with weight loss success among adults enrolled in a weight loss program. *Journal of Behavioral Medicine*, *39*(4), 727–732. https://doi.org/10.1007/s10865-016-9728-8

Braver, T. S., Cohen, J. D., Nystrom, L. E., Jonides, J., Smith, E. E., & Noll, D. C. (1997). A parametric study of prefrontal cortex involvement in human working memory. *Neuroimage*, *5*(1), 49–62.

Brinkworth, G. D., Buckley, J. D., Noakes, M., Clifton, P. M., & Wilson, C. J. (2009). Long-term effects of a very low-carbohydrate diet and a low-fat diet on mood and cognitive function. *Archives of Internal Medicine*, *169*(20), 1873–1880.

Brooks, S. J., Wiemerslage, L., Burch, K., Maiorana, S., Cocolas, E., Schiöth, H., Kamaloodien, K., & Stein, D. (2017). The impact of cognitive training in substance use disorder: the effect of working memory training on impulse control in methamphetamine users. *Psychopharmacology*, *234*(12), 1911–1921. https://doi.org/10.1007/s00213-017-4597-6

Bryan, J., & Tiggemann, M. (2001). The effect of weight-loss dieting on cognitive performance and psychological well-being in overweight women. *Appetite*, *36*(2), 147–156. https://doi.org/10.1006/appe.2000.0389

Bull, F. C., Maslin, T. S., & Armstrong, T. (2009). Global physical activity questionnaire (GPAQ): nine country reliability and validity study. *Journal of Physical Activity and Health*, *6*(6), 790–804.

Calvo, D., Galioto, R., Gunstad, J., & Spitznagel, M. B. (2014). Uncontrolled eating is associated with reduced executive functioning. *Clinical Obesity*, *4*(3), 172–179. https://doi.org/10.1111/cob.12058

Cami, J., & Farre, M. (2003). Drug Addiction. *The New England Journal of Medicine*, *10*(349), 975–986. https://doi.org/10.1016/S0140-6736(77)90599-2

Camps, S. G. J. A., Verhoef, S. P. M., & Westerterp, K. R. (2013). Weight loss, weight maintenance, and adaptive thermogenesis. *American Journal of Clinical Nutrition*, *97*(5), 990–994. https://doi.org/10.3945/ajcn.112.050310

Cheatham, R. A., Roberts, S. B., Das, S. K., Gilhooly, C. H., Golden, J. K., Hyatt, R., Lerner, D., Saltzman, E., & Lieberman, H. R. (2009). Long-term effects of provided low and high glycemic load low energy diets on mood and cognition. *Physiology and Behavior*, *98*(3), 374–379. https://doi.org/10.1016/j.physbeh.2009.06.015

Choo, J., & Kang, H. (2015). Predictors of initial weight loss among women with abdominal obesity: a path model using self-efficacy and health-promoting behaviour. *Journal of Advanced Nursing*, *71*(5), 1087–1097.

Ciszewski, S., Francis, K., Mendella, P., Bissada, H., & Tasca, G. A. (2014). Validity and reliability of the Behavior Rating Inventory of Executive Function - Adult Version in a clinical sample with eating disorders. *Eating Behaviors*, *15*(2), 175–181. https://doi.org/10.1016/j.eatbeh.2014.01.004

Clamp, L. D., Hume, D. J., Lambert, E. v., & Kroff, J. (2017). Enhanced insulin sensitivity in successful, long-term weight loss maintainers compared with matched controls with no weight loss history. *Nutrition & Diabetes*, *7*(6), e282. https://doi.org/10.1038/nutd.2017.31

Clark, M. M., Abrams, D. B., Niaura, R. S., Eaton, C. A., & et al. (1991). Self-efficacy in weight management. *Journal of Consulting and Clinical Psychology*, *59*(5), 739–744. https://doi.org/10.1037//0022-006x.59.5.739

Clark, M. M., Cargill, B. R., Medeiros, M. L., & Pera, V. (1996). Changes in self-efficacy following obesity treatment. *Obesity Research*, *4*(2), 179–181.

Clarkson, J. J., Hirt, E. R., Chapman, D. A., & Jia, L. (2011). The impact of illusory fatigue on executive control: Do perceptions of depletion impair working memory capacity? *Social Psychological and Personality Science*, *2*(3), 231–238. https://doi.org/10.1177/1948550610386628

Cserjési, R., Luminet, O., Poncelet, A. S., & Lénárd, L. (2009). Altered executive function in obesity. Exploration of the role of affective states on cognitive abilities. *Appetite*, *52*(2), 535–539. https://doi.org/10.1016/j.appet.2009.01.003

Daly, M., McMinn, D., & Allan, J. L. (2015). A bidirectional relationship between physical activity and executive function in older adults. *Frontiers in Human Neuroscience*, *8*(JAN), 1–9. https://doi.org/10.3389/fnhum.2014.01044

Dassen, F. C. M., Houben, K., van Breukelen, G. J. P., & Jansen, A. (2018). Gamified working memory training in overweight individuals reduces food intake but not body weight. *Appetite*, *124*, 89–98. https://doi.org/10.1016/j.appet.2017.05.009

Dassen, F.C., Houben, K., Allom, V. and Jansen, A., 2018. Self-regulation and obesity: the role of executive function and delay discounting in the prediction of weight loss. *Journal of behavioral medicine, 41(6),* 806-818.

Davids, R. C. D., Groen, Y., Berg, I. J., Tucha, O. M., & van Balkom, I. D. C. (2016). Executive Functions in Older Adults With Autism Spectrum Disorder: Objective Performance and Subjective Complaints. *Journal of Autism and Developmental Disorders*, *46*(9), 2859–2873. https://doi.org/10.1007/s10803-016-2831-4

Demant, K. M., Vinberg, M., Kessing, L. v., & Miskowiak, K. W. (2015). Assessment of subjective and objective cognitive function in bipolar disorder: Correlations, predictors and the relation to psychosocial function. *Psychiatry Research*, *229*(1–2), 565–571. https://doi.org/10.1016/j.psychres.2015.05.022

de Witt Huberts, J. C., Evers, C., & de Ridder, D. T. D. (2013). Double trouble: Restrained eaters do not eat less and feel worse. *Psychology and Health*, *28*(6), 686–700. https://doi.org/10.1080/08870446.2012.751106

Diamond, A. (2013). Executive Functions. *Annu. Rev. Psychol*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Dohle, S., Diel, K. and Hofmann, W., 2018. Executive functions and the self-regulation of eating behavior: A review. *Appetite, 124*, 4-9.

Doytch, N., Dave, D. M., & Kelly, I. R. (2016). Global evidence on obesity and related outcomes: An overview of prevalence, trends, and determinants. *Eastern Economic Journal*, *42*(1), 7–28. https://doi.org/10.1057/eej.2014.37

Emery, R. L., & Levine, M. D. (2017). Questionnaire and behavioral task measures of impulsivity are differentially associated with body mass index: A comprehensive meta-analysis. *Frontiers in Physiology*, *8*(JUL). https://doi.org/10.3389/fpsyg.2017.01222

Ersche, K. D., Clark, L., London, M., Robbins, T. W., & Sahakian, B. J. (2006). Profile of executive and memory function associated with amphetamine and opiate dependence. *Neuropsychopharmacology*, *31*(5), 1036–1047. https://doi.org/10.1038/sj.npp.1300889

Espeland, M. A., Rapp, S. R., Bray, G. A., Houston, D. K., Johnson, K. C., Kitabchi, A. E., Hergenroeder, A. L., Williamson, J., Jakicic, J. M., van Dorsten, B., & Kritchevsky, S. B. (2014). Long-term impact of behavioral weight loss intervention on cognitive function. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*, *69*(9), 1101–1108. https://doi.org/10.1093/gerona/glu031

Fairburn, C. G., Cooper, Z., & O'Conner, M. (1993). The Eating Disorder Examination. *International Journal of Eating Disorders*, *6*, 1–8. https://doi.org/10.1007/978-981-287-104-6_101

Fan, M., & Jin, Y. (2014). Obesity and self-control: Food consumption, physical activity, and weight-loss intention. *Applied Economic Perspectives and Policy*, *36*(1), 125–145.

Favieri, F., Forte, G. and Casagrande, M., 2019. The executive functions in overweight and obesity: A systematic review of neuropsychological cross-sectional and longitudinal studies. *Frontiers in psychology, 10*, 2126.

Fernández-Serrano, M. J., Pérez-García, M., Perales, J. C., & Verdejo-García, A. (2010). Prevalence of executive dysfunction in cocaine, heroin and alcohol users enrolled in therapeutic communities. *European Journal of Pharmacology*, *626*(1), 104–112. https://doi.org/10.1016/j.ejphar.2009.10.019

Fitzpatrick, S., Gilbert, S. and Serpell, L., 2013. Systematic review: are overweight and obese individuals impaired on behavioural tasks of executive functioning?. *Neuropsychology review, 23(2)*, 138-156.

Flint, A., Gregersen, N. T., Gluud, L. L., Møller, B. K., Raben, A., Tetens, I., Verdich, C., & Astrup, A. (2007). Associations between postprandial insulin and blood glucose responses, appetite sensations and energy intake in normal weight and overweight individuals: A meta-analysis of test meal studies. *British Journal of Nutrition*, *98*(1), 17–25. https://doi.org/10.1017/S000711450768297X

Flint, A., Raben, A., Blundell, J. E., & Astrup, A. (2000). Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. *International Journal of Obesity*, *24*(1), 38–48.

Forsythe, L. K., Wallace, J. M. W., & Livingstone, M. B. E. (2008). Obesity and inflammation: The effects of weight loss. *Nutrition Research Reviews*, *21*(2), 117–133. https://doi.org/10.1017/S0954422408138732

Frecka, J. M., & Mattes, R. D. (2008). Possible entrainment of ghrelin to habitual meal patterns in humans. *American Journal of Physiology - Gastrointestinal and Liver Physiology*, *294*(3), 699–707. https://doi.org/10.1152/ajpgi.00448.2007

Friese, M., Hofmann, W., & Wänke, M. (2008). When impulses take over: Moderated predictive validity of explicit and implicit attitude measures in predicting food choice and consumption behaviour. *British Journal of Social Psychology*, *47*(3), 397–419. https://doi.org/10.1348/014466607X241540

Fuermaier, A. B. M., Tucha, L., Aschenbrenner, S., Kaunzinger, I., Hauser, J., Weisbrod, M., Lange, K. W., & Tucha, O. (2015). Cognitive impairment in adult ADHD-perspective matters! *Neuropsychology*, *29*(1), 45–58. https://doi.org/10.1037/neu0000108

Galgani, J. E., Moro, C., & Ravussin, E. (2008). Metabolic flexibility and insulin resistance. *American Journal of Physiology - Endocrinology and Metabolism*, *295*(5), 1009–1017. https://doi.org/10.1152/ajpendo.90558.2008

Ganley, R. M. (1989). Emotion and eating in obesity: A review of the literature. *International Journal of Eating Disorders*, *8*(3), 343–361.

Garaulet, M., Canteras, M., Morales, E., López-Guimera, G., Sánchez-Carracedo, D., & Corbalán-Tutau, M. D. (2012). Validación de un cuestionario de comedores emocionales para uso en casos de obesidad; cuestionario de comedor emocional (CCE). *Nutricion Hospitalaria*, *27*(2), 645–651. https://doi.org/10.3305/nh.2012.27.2.5659

García-García, I., Horstmann, A., Jurado, M. A., Garolera, M., Chaudhry, S. J., Margulies, D. S., Villringer, A., & Neumann, J. (2014). Reward processing in obesity, substance addiction and non-substance addiction. *Obesity Reviews*, *15*(11), 853–869. https://doi.org/10.1111/obr.12221

Garlinghouse, M. A., Roth, R. M., Isquith, P. K., Flashman, L. A., & Saykin, A. J. (2010). Subjective rating of working memory is associated with frontal lobe volume in schizophrenia. *Schizophrenia Research*, *120*(1–3), 71–75. https://doi.org/10.1016/j.schres.2010.02.1067

Gettens, K.M. and Gorin, A.A., 2017. Executive function in weight loss and weight loss maintenance: a conceptual review and novel neuropsychological model of weight control. *Journal of behavioral medicine, 40(5)*, 687-701.

Gelonch, O., Garolera, M., Valls, J., Rosselló, L., & Pifarré, J. (2016). Executive function in fibromyalgia: Comparing subjective and objective measures. *Comprehensive Psychiatry*, *66*, 113–122. https://doi.org/10.1016/j.comppsych.2016.01.002

Gevins, A., & Smith, M. E. (2000). Neurophysiological measures of working memory and individual differences in cognitive ability and cognitive style. *Cerebral Cortex*, *10*(9), 829–839. https://doi.org/10.1093/cercor/10.9.829

Gould, T. J. (2010). Addiction and cognition. *Addiction Science & Clinical Practice*, *5*(2), 4–14.

Goverover, Y., Kalmar, J., Gaudino-Goering, E., Shawaryn, M., Moore, N. B., Halper, J., & DeLuca, J. (2005). The relation between subjective and objective measures of everyday life activities in persons with multiple sclerosis. *Archives of Physical Medicine and Rehabilitation*, *86*(12), 2303–2308. https://doi.org/10.1016/j.apmr.2005.05.016

Greenland, S., Senn, S. J., Rothman, K. J., Carlin, J. B., Poole, C., Goodman, S. N., & Altman, D. G. (2016). Statistical tests, P values, confidence intervals, and power: a guide to misinterpretations. *European Journal of Epidemiology*, *31*(4), 337–350.

Green, M. W., Elliman, N. A., & Kretsch, M. J. (2005). Weight loss strategies, stress, and cognitive function: Supervised versus unsupervised dieting. *Psychoneuroendocrinology*, *30*(9), 908–918. https://doi.org/10.1016/j.psyneuen.2005.05.005

Green, M. W., Elliman, N. A., & Rogers, P. J. (1997). Impaired cognitive processing in dieters: Failure of attention focus or resource capacity limitation? *British Journal of Health Psychology*, *2*(3), 259–267. https://doi.org/10.1111/j.2044-8287.1997.tb00540.x

Guh, D. P., Zhang, W., Bansback, N., Amarsi, Z., Birmingham, C. L., & Anis, A. H. (2009). The incidence of co-morbidities related to obesity and overweight: A systematic review and meta-analysis. *BMC Public Health*, *9*, 1–20. https://doi.org/10.1186/1471-2458-9-88

Gunn, R. L., Gerst, K. R., Wiemers, E. A., Redick, T. S., & Finn, P. R. (2018). Predictors of Effective Working Memory Training in Individuals with Alcohol Use Disorders. *Alcoholism, Clinical and Experimental Research*, *42*(12), 2432–2441. https://doi.org/10.1111/acer.13892

Gunstad, J., Paul, R. H., Cohen, R. A., Tate, D. F., Spitznagel, M. B., & Gordon, E. (2007). Elevated body mass index is associated with executive dysfunction in otherwise healthy adults. *Comprehensive Psychiatry*, *48*(1), 57–61. https://doi.org/10.1016/j.comppsych.2006.05.001

Habib, S. H., & Saha, S. (2010). Burden of non-communicable disease: Global overview. *Diabetes and Metabolic Syndrome: Clinical Research and Reviews*, *4*(1), 41–47. https://doi.org/10.1016/j.dsx.2008.04.005

Hadjiefthyvoulou, F., Fisk, J. E., Montgomery, C., & Bridges, N. (2012). Self-reports of executive dysfunction in current ecstasy/polydrug users. *Cognitive and Behavioral Neurology*, *25*(3), 128–138. https://doi.org/10.1097/WNN.0b013e318261459c

Hagen, E., Erga, A. H., Hagen, K. P., Nesvåg, S. M., McKay, J. R., Lundervold, A. J., & Walderhaug, E. (2016). Assessment of executive function in patients with substance use disorder: A comparison of inventory- and performance-based assessment. *Journal of Substance Abuse Treatment*, *66*, 1–8. https://doi.org/10.1016/j.jsat.2016.02.010

Hall, P. A. (2012). Executive control resources and frequency of fatty food consumption: Findings from an age-stratified community sample. *Health Psychology*, *31*(2), 235–241. https://doi.org/10.1037/a0025407

Hall, P. A., Fong, G. T., Epp, L. J., & Elias, L. J. (2008a). Executive function moderates the intention-behavior link for physical activity and dietary behavior. *Psychology and Health*, *23*(3), 309–326. https://doi.org/10.1080/14768320701212099

Hall, P. A., Fong, G. T., Epp, L. J., & Elias, L. J. (2008b). Executive function moderates the intention-behavior link for physical activity and dietary behavior. *Psychology and Health*, *23*(3), 309–326. https://doi.org/10.1080/14768320701212099

Halyburton, A. K., Brinkworth, G. D., Wilson, C. J., Noakes, M., Buckley, J. D., Keogh, J. B., & Clifton, P. M. (2007). Low- and high-carbohydrate weight-loss diets have similar effects on mood but not cognitive performance. *American Journal of Clinical Nutrition*, *86*(3), 580–587. https://doi.org/10.1093/ajcn/86.3.580

Hart, K. E., & Chiovari, P. (1998). Inhibition of eating behavior: Negative cognitive effects of dieting. *Journal of Clinical Psychology*, *54*(4), 427–430. https://doi.org/10.1002/(SICI)1097-4679(199806)54:4<427::AID-JCLP4>3.0.CO;2-K

Hege, M. A., Stingl, K. T., Ketterer, C., Häring, H. U., Heni, M., Fritsche, A., & Preissl, H. (2013). Working memory-related brain activity is associated with outcome of lifestyle intervention. *Obesity*, *21*(12), 2488–2494. https://doi.org/10.1002/oby.20442

Hendershot, C. S., Wardell, J. D., Vandervoort, J., McPhee, M. D., Keough, M. T., & Quilty, L. C. (2018). Randomized Trial of Working Memory Training as an Adjunct to Inpatient Substance Use Disorder Treatment. *PSYCHOLOGY OF ADDICTIVE BEHAVIORS*, *32*(8), 861–872. https://doi.org/10.1037/adb0000415

Hester, R., & Garavan, H. (2005). Working memory and executive function: The influence of content and load on the control of attention. *Memory and Cognition*, *33*(2), 221–233. https://doi.org/10.3758/BF03195311

Hockey, A., & Geffen, G. (2004). The concurrent validity and test-retest reliability of a visuospatial working memory task. *Intelligence*, *32*(6), 591–605. https://doi.org/10.1016/j.intell.2004.07.009

Hofmann, W., Friese, M., & Strack, F. (2009). Impulse and Self-Control From a Dual-Systems Perspective. *Perspectives on Psychological Science*, *4*(2), 162–176. https://doi.org/10.1111/j.1745-6924.2009.01116.x

Hofmann, W., Gschwendner, T., Friese, M., Wiers, R. W., & Schmitt, M. (2008). Working Memory Capacity and Self-Regulatory Behavior: Toward an Individual Differences Perspective on Behavior Determination by Automatic Versus Controlled Processes. *Journal of Personality and Social Psychology*, *95*(4), 962–977. https://doi.org/10.1037/a0012705

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences*, *16*(3), 174–180. https://doi.org/10.1016/j.tics.2012.01.006

Hone-Blanchet, A., & Fecteau, S. (2014). Overlap of food addiction and substance use disorders definitions: Analysis of animal and human studies. *Neuropharmacology*, *85*, 81–90. https://doi.org/10.1016/j.neuropharm.2014.05.019

Houben, K., Dassen, F. C. M., & Jansen, A. (2016). Taking control: Working memory training in overweight individuals increases self-regulation of food intake. *Appetite*, *105*, 567–574. https://doi.org/10.1016/j.appet.2016.06.029

Houben, K., Wiers, R. W., & Jansen, A. (2011). Getting a Grip on Drinking Behavior: Training Working Memory to Reduce Alcohol Abuse. *Psychological Science*, *22*(7), 968–975. https://doi.org/10.1177/0956797611412392

Hume, D., Hons, M., Kroff, J., Clamp, L. D., Hons, M., & Lambert, E. v. (2015). Compensations for Weight Loss in Successful and Unsuccessful Dieters. *American Journal of Health Behavior*, *39*(5), 589–600.

Hume, D. J. (2015). Mind the Gap: Brain-Behaviour Barriers to Successful Weight Loss Maintenance. *University of Cape Town*.

Hume, D. J., Howells, F. M., Karpul, D., Rauch, H. G. L., Kroff, J., & Lambert, E. V. (2015). Cognitive control over visual food cue saliency is greater in reduced-overweight/obese but not in weight relapsed women: An EEG study. *Eating Behaviors*, *19*, 76–80. https://doi.org/10.1016/j.eatbeh.2015.06.013

Ifland, J. R., Preuss, H. G., Marcus, M. T., Rourke, K. M., Taylor, W. C., Burau, K., Jacobs, W. S., Kadish, W., & Manso, G. (2009). Refined food addiction: A classic substance use disorder. *Medical Hypotheses*, *72*(5), 518–526. https://doi.org/10.1016/j.mehy.2008.11.035

Jacola, L. M., Willard, V. W., Ashford, J. M., Ogg, R. J., Scoggins, M. A., Jones, M. M., Wu, S., & Conklin, H. M. (2014). Clinical utility of the N-back task in functional neuroimaging studies of working memory. *Journal of Clinical and Experimental Neuropsychology*, *36*(8), 875–886. https://doi.org/10.1080/13803395.2014.953039

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences*, *105*(19), 6829–6833. https://doi.org/10.3758/s13423-014-0699-x

Jaeggi, S. M., Buschkuehl, M., Perrig, W. J., & Meier, B. (2010). The concurrent validity of the N-back task as a working memory measure. *Memory*, *18*(4), 394–412. https://doi.org/10.1080/09658211003702171

Jovanovski, D., Erb, S., & Zakzanis, K. K. (2005). Neurocognitive deficits in cocaine users: A quantitative review of the evidence. *Journal of Clinical and Experimental Neuropsychology*, *27*(2), 189–204. https://doi.org/10.1080/13803390490515694

Kemps, E., & Tiggemann, M. (2005). Working memory performance and preoccupying thoughts in female dieters: Evidence for a selective central executive impairment. *British Journal of Clinical Psychology*, *44*(3), 357–366. https://doi.org/10.1348/014466505X35272

Kemps, E., Tiggemann, M., & Marshall, K. (2005). Relationship between dieting to lose weight and the functioning of the central executive. *Appetite*, *45*(3), 287–294. https://doi.org/10.1016/j.appet.2005.07.002

Keskin, M., Kurtoglu, S., Kendirci, M., Atabek, M. E., & Yazici, C. (2005). Homeostasis model assessment is more reliable than the fasting glucose/insulin ratio and quantitative insulin sensitivity check index for assessing insulin resistance among obese children and adolescents. *Pediatrics*, *115*(4). https://doi.org/10.1542/peds.2004-1921

Khemiri, L., Brynte, C., Stunkel, A., Klingberg, T., & Jayaram-Lindström, N. (2019). Working Memory Training in Alcohol Use Disorder: A Randomized Controlled Trial. *Alcoholism: Clinical and Experimental Research*, *43*(1), 135–146. https://doi.org/10.1111/acer.13910

Klingberg, T. (2010). Training and plasticity of working memory. *Trends in Cognitive Sciences*, *14*(7), 317–324. https://doi.org/10.1016/j.tics.2010.05.002

Koerts, J., Tucha, L., Leenders, K. L., van Beilen, M., Brouwer, W. H., & Tucha, O. (2011). Subjective and objective assessment of executive functions in Parkinson's disease. *Journal of the Neurological Sciences*, *310*(1–2), 172–175. https://doi.org/10.1016/j.jns.2011.07.009

Koven, N. S., & Senbonmatsu, R. (2013). A neuropsychological evaluation of orthorexia nervosa. *Open Journal of Psychiatry*, *03*(02), 214–222. https://doi.org/10.4236/ojpsych.2013.32019

Lawson, E. A., Eddy, K. T., Donoho, D., Misra, M., Miller, K. K., Meenaghan, E., Lydecker, J., Herzog, D., & Klibanski, A. (2011). Appetite-regulating hormones cortisol and peptide YY are associated with disordered eating psychopathology, independent of body mass index. *European Journal of Endocrinology/European Federation of Endocrine Societies*, *164*(2), 253–261. https://doi.org/10.1530/EJE-10-0523.Appetite-regulating

Leclerc, E., Trevizol, A. P., Grigolon, R. B., Subramaniapillai, M., McIntyre, R. S., Brietzke, E., & Mansur, R. B. (2020). The effect of caloric restriction on working memory in healthy non-obese adults. *CNS Spectrums*, *25*(1), 2–8. https://doi.org/10.1017/S1092852918001566

Lowe, M. R., & Levine, A. S. (2005). Eating motives and the controversy over dieting: Eating less than needed versus less than wanted. *Obesity Research*, *13*(5), 797–806. https://doi.org/10.1038/oby.2005.90

MacKillop, J., Amlung, M. T., Few, L. R., Ray, L. A., Sweet, L. H., & Munafò, M. R. (2011). Delayed reward discounting and addictive behavior: A meta-analysis. *Psychopharmacology*, *216*(3), 305–321. https://doi.org/10.1007/s00213-011-2229-0

MacLean, P. S., Wing, R. R., Davidson, T., Epstein, L., Goodpaster, B., Hall, K. D., Levin, B. E., Perri, M. G., Rolls, B. J., Rosenbaum, M., Rothman, A. J., & Ryan, D. (2015). NIH working group report: Innovative research to improve maintenance of weight loss. *Obesity*, *23*(1), 7–15. https://doi.org/10.1002/oby.20967

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: an integrative review. *Psychological Bulletin*, *109*(2), 163.

Manning, V., Verdejo-Garcia, A., & Lubman, D. I. (2017). Neurocognitive impairment in addiction and opportunities for intervention. *Current Opinion in Behavioral Sciences*, *13*, 40–45. https://doi.org/10.1016/j.cobeha.2016.10.003

Manoach, D. S., Schlaug, G., Siewert, B., Darby, D. G., Bly, B. M., Benfield, A., Edelman, R. R., & Warach, S. (1997). Prefrontal cortex fMRI signal changes are correlated with working memory load. *Neuroreport*, *8*(2), 545–549.

Martin, C. K., Anton, S. D., Han, H., York-crowe, E., & M, L. (2007). Examination of Cognitive Function During Six Months of Calorie Restriction : Results of a Randomized Controlled Trial. *Rejuvenation Research*, *10*(2), 179–190. https://doi.org/10.1089/rej.2006.0502.Examination

Matthews, D. R., Hosker, J. P., Rudenski, A. S., Naylor, B. A., Treacher, D. F., & Turner, R. C. (1985). Homeostasis model assessment: insulin resistance and β-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*, *28*(7), 412–419. https://doi.org/10.1007/BF00280883

Mcauley, T., Chen, S., Goos, L., Schachar, R., & Crosbie, J. (2010). Is the behavior rating inventory of executive function more strongly associated with measures of impairment or executive function? *Journal of the International Neuropsychological Society*, *16*(3), 495–505. https://doi.org/10.1017/S1355617710000093

McCabe, D. P., Mcdaniel, M. A., Hambrick, D. Z., Roediger, H. L., Mcdaniel, M. A., Balota, D. A., & Hambrick, D. Z. (2010). The Relationship between Working memory capacity and Executive Function. *Neuropsychology*, *24*(2), 222–243. https://doi.org/10.1037/a0017619.The

McHorney, C. A., Ware Jr, J. E., Lu, J. F. R., & Sherbourne, C. D. (1994). The MOS 36-item Short-Form Health Survey (SF-36): III. Tests of data quality, scaling assumptions, and reliability across diverse patient groups. *Medical Care*, 40–66.

McLean, S. A., Paxton, S. J., & Wertheim, E. H. (2010). Factors associated with body dissatisfaction and disordered eating in women in midlife. *International Journal of Eating Disorders*, *43*(6), 527–536. https://doi.org/10.1002/eat.20737

Melby, C. L., Paris, H. L., Foright, R. M., & Peth, J. (2017). Attenuating the biologic drive for weight regain following weight loss: Must what goes down always go back up? *Nutrients*, *9*(5). https://doi.org/10.3390/nu9050468

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, *49*(2), 270–291. https://doi.org/10.1037/a0028228

Meule, A. (2016). Dieting and food cue-related working memory performance. *Frontiers in Psychology*, *7*(DEC), 1–9. https://doi.org/10.3389/fpsyg.2016.01944

Miller, K. M., Price, C. C., Okun, M. S., Montijo, H., & Bowers, D. (2009). Is the N-back task a valid neuropsychological measure for assessing working memory? *Archives of Clinical Neuropsychology*, *24*(7), 711–717. https://doi.org/10.1093/arclin/acp063

Milner, B. (1963). Effects of different brain lesions on card sorting: The role of the frontal lobes. *Archives of Neurology*, *9*(1), 90–100.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex "Frontal Lobe" Tasks: A Latent Variable Analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Mohammadnia, S., Bigdeli, I., Mashhadi, A., Ghanaei Chamanabad, A., & Roth, R. M. (2020). Behavior Rating Inventory of Executive Function–adult version (BRIEF-A) in Iranian University students: Factor structure and relationship to depressive symptom severity. *Applied Neuropsychology:Adult*, *0*(0), 1–7. https://doi.org/10.1080/23279095.2020.1810689

Mond, J. M., Hay, P. J., Rodgers, B., Owen, C., & Beumont, P. J. V. (2004). Validity of the Eating Disorder Examination Questionnaire (EDE-Q) in screening for eating disorders in community samples. *Behaviour Research and Therapy*, *42*(5), 551–567. https://doi.org/10.1016/S0005-7967(03)00161-X

Morrison, A. B., & Chein, J. M. (2011). Does working memory training work? the promise and challenges of enhancing cognition by training working memory. *Psychonomic Bulletin and Review*, *18*(1), 46–60. https://doi.org/10.3758/s13423-010-0034-0

Morton, G. J., Cummings, D. E., Baskin, D. G., Barsh, G. S., & Schwartz, M. W. (2006). Central nervous system control of food intake and body weight. *Nature*, *443*(7109), 289–295. https://doi.org/10.1038/nature05026

National Heart Lung and Blood Institute. (1998). Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes Res*, *6*, 51S-210S.

Nederkoorn, C., Houben, K., Hofmann, W., Roefs, A., & Jansen, A. (2010). Control yourself or just eat what you like? Weight gain over a year is predicted by an interactive effect of response inhibition and implicit preference for snack foods. *Health Psychology*, *29*(4), 389–393. https://doi.org/10.1037/a0019921

Nelson, H. E. (1976). A modified card sorting test sensitive to frontal lobe defects. *Cortex*, *12*(4), 313–324.

Nelson, K. M., Weinsier, R. L., James, L. D., Darnell, B., Hunter, G., & Long, C. L. (1992). Effect of weight reduction on resting energy expenditure, substrate utilization, and the thermic effect of food in moderately obese women. *American Journal of Clinical Nutrition*, *55*(5), 924–933. https://doi.org/10.1093/ajcn/55.5.924

Niendam, T. A., Horwitz, J., Bearden, C. E., & Cannon, T. D. (2007). Ecological assessment of executive dysfunction in the psychosis prodrome: A pilot study. *Schizophrenia Research*, *93*(1–3), 350–354. https://doi.org/10.1016/j.schres.2007.03.009

Nordvall, O., Jonsson, B., & Neely, A. S. (2017). Self-reported and performance-based measures of executive functions in interned youth. *Psychology, Crime and Law*, *23*(3), 240–253. https://doi.org/10.1080/1068316X.2016.1239725

Petry, N. M., Barry, D., Pietrzak, R. H., & Wagner, J. A. (2008). Overweight and obesity are associated with psychiatric disorders: results from the National Epidemiologic Survey on Alcohol and Related Conditions. *Psychosomatic Medicine*, *70*(3), 288–297.

Potvin, S., Pelletier, J., Grot, S., Hébert, C., Barr, A., & Lecomte, T. (2018). Cognitive deficits in individuals with methamphetamine use disorder: A meta-analysis. *Addictive Behaviors*, *80*(September 2017), 154–160. https://doi.org/10.1016/j.addbeh.2018.01.021

Potvin, S., Stavro, K., Rizkallah, É., & Pelletier, J. (2014). Cocaine and cognition: A systematic quantitative review. *Journal of Addiction Medicine*, *8*(5), 368–376. https://doi.org/10.1097/ADM.0000000000000066

Raben, A., Andersen, H. B., Christensen, N. J., Madsen, J., Holst, J. J., & Astrup, A. (1994). Evidence for an abnormal postprandial response to a high-fat meal in women predisposed to obesity. *American Journal of Physiology-Endocrinology and Metabolism*, *267*(4), E549–E559.

Rabin, L. A., Roth, R. M., Isquith, P. K., Wishart, H. A., Nutter-Upham, K. E., Pare, N., Flashman, L. A., & Saykin, A. J. (2006). Self- and informant reports of executive function on the BRIEF-A in MCI and older adults with cognitive complaints. *Archives of Clinical Neuropsychology*, *21*(7), 721–732. https://doi.org/10.1016/j.acn.2006.08.004

Rass, O., Schacht, R. L., Buckheit, K., Johnson, M. W., Strain, E. C., & Mintzer, M. Z. (2015). A randomized controlled trial of the effects of Working Memory Training in Methadone Maintenance Patients. *Drug Alcohol Dependence*, *156*(2011), 38–46. https://doi.org/10.1016/j.drugalcdep.2015.08.012.A

Reyes, N. R., Oliver, T. L., Klotz, A. A., LaGrotte, C. A., vander Veur, S. S., Virus, A., Bailer, B. A., & Foster, G. D. (2012). Similarities and Differences between Weight Loss Maintainers and Regainers: A Qualitative Analysis. *Journal of the Academy of Nutrition and Dietetics*, *112*(4), 499–505. https://doi.org/10.1016/j.jand.2011.11.014

Roberts, R., & Gibson, E. (2002). Individual differences in sentence memory. *Journal of Psycholinguistic Research*, *31*(6), 573–598. https://doi.org/10.1023/A:1021213004302

Rochette, A. D., Spitznagel, M. B., Strain, G., Devlin, M., Crosby, R. D., Mitchell, J. E., Courcoulas, A., & Gunstad, J. (2016). Mild cognitive impairment is prevalent in persons with severe obesity. *Obesity*, *24*(7), 1427–1429. https://doi.org/10.1002/oby.21514.This

Rø, Ø., Reas, D. L., & Stedal, K. (2015). Eating Disorder Examination Questionnaire (EDE-Q) in Norwegian Adults: Discrimination between Female Controls and Eating Disorder Patients. *European Eating Disorders Review*, *23*(5), 408–412. https://doi.org/10.1002/erv.2372

Roth, R. M., Isquith, P. K., & Gioia, G. A. (2005). BRIEF-A: Behavior Rating Inventory of Executive Function-adult Version. *(Psychological Assessment Resource: Lutz, FL)*.

Rouel, M., Raman, J., Hay, P., & Smith, E. (2016). Validation of the Behaviour Rating Inventory of Executive Function – Adult Version (BRIEF-A) in the obese with and without binge eating disorder. *Eating Behaviors*, *23*, 58–65. https://doi.org/10.1016/j.eatbeh.2016.07.010

Savastano, S., Belfiore, A., di Somma, C., Mauriello, C., Rossi, A., Pizza, G., de Rosa, A., Prestieri, G., Angrisani, L., & Colao, A. (2010). Validity of bioelectrical impedance analysis to estimate body

composition changes after bariatric surgery in premenopausal morbidly women. *Obesity Surgery*, *20*(3), 332–339.

Schmeichel, B. J., & Demaree, H. A. (2010). Working Memory Capacity and Spontaneous Emotion Regulation: High Capacity Predicts Self-Enhancement in Response to Negative Feedback. *Emotion*, *10*(5), 739–744. https://doi.org/10.1037/a0019355

Schulz, K. F., & Grimes, D. A. (2002). Blinding in randomised trials: Hiding who got what. *Lancet*, *359*(9307), 696–700. https://doi.org/10.1016/S0140-6736(02)07816-9

Shwartz, S.K., Roper, B.L., Arentsen, T.J., Crouse, E.M. and Adler, M.C., 2020. The Behavior Rating Inventory of Executive Function®-Adult Version is related to emotional distress, not executive dysfunction, in a veteran sample. *Archives of Clinical Neuropsychology, 35(6),* 701-716.

Schwarzer, R., & Jerusalem, M. (1995). Generalized self-efficacy scale. *Measures in Health Psychology: A User's Portfolio. Causal and Control Beliefs*, *1*(1), 35–37.

Sherer, M., Maddux, J. E., Mercandante, B., Prentice-Dunn, S., Jacobs, B., & Rogers, R. W. (1982). The self-efficacy scale: Construction and validation. *Psychological Reports*, *51*(2), 663–671.

Shipstead, Z., Redick, T. S., & Engle, R. W. (2012). Is working memory training effective? *Psychological Bulletin*, *138*(4), 628–654. https://doi.org/10.1037/a0027473

Siervo, M., Nasti, G., Stephan, B. C. M., Papa, A., Muscariello, E., Wells, J. C. K., Prado, C. M., & Colantuoni, A. (2012). Effects of intentional weight loss on physical and cognitive function in middle-aged and older obese participants: A pilot study. *Journal of the American College of Nutrition*, *31*(2), 79–86. https://doi.org/10.1080/07315724.2012.10720012

Simon, S. L., Domier, C., Carnell, J., Brethen, P., Rawson, R., & Ling, W. (2000). Cognitive impairment in individuals currently using methamphetamine. *The American Journal on Addictions*, *17*(9), 222–231. https://doi.org/10.1007/s11916-013-0344-9

Smith, E., Hay, P., Campbell, L., & Trollor, J. N. (2011). A review of the association between obesity and cognitive function across the lifespan: Implications for novel approaches to prevention and treatment. *Obesity Reviews*, *12*(9), 740–755. https://doi.org/10.1111/j.1467-789X.2011.00920.x

Snider, S. E., Deshpande, H. U., Lisinski, J. M., Koffarnus, M. N., LaConte, S. M., & Bickel, W. K. (2018). Working Memory Training Improves Alcohol Users' Episodic Future Thinking: A Rate-Dependent Analysis. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *3*(2), 160–167. https://doi.org/10.1016/j.bpsc.2017.11.002

Snyder, H. R. (2013). Major depressive disorder is associated with broad impairments on neuropsychological measures of executive function: A meta-analysis and review. *Psychological Bulletin*, *139*(1), 81–132. https://doi.org/10.1037/a0028727

Spencer-Smith, M., & Klingberg, T. (2015). Benefits of a working memory training program for inattention in daily life: A systematic review and meta-analysis. *PLoS ONE*, *10*(3). https://doi.org/10.1371/journal.pone.0119522

Stavro, K., Pelletier, J., & Potvin, S. (2013). Widespread and sustained cognitive deficits in alcoholism: A meta-analysis. *Addiction Biology*, *18*(2), 203–213. https://doi.org/10.1111/j.1369-1600.2011.00418.x

Stice, E., Burger, K., & Yokum, S. (2013). Caloric deprivation increases responsivity of attention and reward brain regions to intake, anticipated intake, and images of palatable foods. *NeuroImage*, *67*, 322–330. https://doi.org/10.1016/j.neuroimage.2012.11.028

Stice, E., Sysko, R., Roberto, C. A., & Allison, S. (2010). Are dietary restraint scales valid measures of dietary restriction? Additional objective behavioral and biological data suggest not. *Appetite*, *54*(2), 331–339. https://doi.org/10.1016/j.appet.2009.12.009

Storch, E. A., Roberti, J. W., & Roth, D. A. (2004). Factor structure, concurrent validity, and internal consistency of the beck depression inventory—second edition in a sample of college students. *Depression and Anxiety*, *19*(3), 187–189.

Stroebe, W., Mensink, W., Aarts, H., Schut, H., & Kruglanski, A. W. (2008). Why dieters fail: Testing the goal conflict model of eating. *Journal of Experimental Social Psychology*, *44*(1), 26–36. https://doi.org/10.1016/j.jesp.2007.01.005

Sun, S. S., Chumlea, W. C., Heymsfield, S. B., Lukaski, H. C., Schoeller, D., Friedl, K., Kuczmarski, R. J., Flegal, K. M., Johnson, C. L., & Hubbard, V. S. (2003). Development of bioelectrical impedance analysis prediction equations for body composition with the use of a multicomponent model for use in epidemiologic surveys. *The American Journal of Clinical Nutrition*, *77*(2), 331–340.

Tangney, J. P., Boone, A. L., & Baumeister, R. F. (2004). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *Journal of Personality*, *72*(2), 173–212. https://doi.org/10.4324/9781315175775

Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner Review: Do performance-based measures and ratings of executive function assess the same construct? *Journal of Child*

Psychology and Psychiatry and Allied Disciplines, *54*(2), 131–143. https://doi.org/10.1111/jcpp.12001

Trinh, O. T. H., do Nguyen, N., van der Ploeg, H. P., Dibley, M. J., & Bauman, A. (2009). Test-retest repeatability and relative validity of the Global Physical Activity Questionnaire in a developing country context. *Journal of Physical Activity and Health*, *6*(s1), S46–S53.

Tuschl, R. J. (1990). From dietary restraint to binge eating: some theoretical considerations. *Appetite*, *14*(2), 105–109.

Vandarakis, D., Salacinski, A. J., & Broeder, C. E. (2013). A comparison of cosmed metabolic systems for the determination of resting metabolic rate. *Research in Sports Medicine*, *21*(2), 187–194. https://doi.org/10.1080/15438627.2012.757226

Verbeken, S., Braet, C., Goossens, L., & van der Oord, S. (2013). Executive function training with game elements for obese children: A novel treatment to enhance self-regulatory abilities for weight-control. *Behaviour Research and Therapy*, *51*(6), 290–299. https://doi.org/10.1016/j.brat.2013.02.006

Verdejo-Garcia, A. (2016). Cognitive training for substance use disorders: Neuroscientific mechanisms. *Neuroscience and Biobehavioral Reviews*, *68*, 270–281. https://doi.org/10.1016/j.neubiorev.2016.05.018

Verdejo-García, A., Bechara, A., Recknor, E. C., & Pérez-García, M. (2006). Executive dysfunction in substance dependent individuals during drug use and abstinence: An examination of the behavioral, cognitive and emotional correlates of addiction. *Journal of the International Neuropsychological Society*, *12*(3), 405–415. https://doi.org/10.1017/S1355617706060486

Verdejo-García, A., & Pérez-García, M. (2007). Profile of executive deficits in cocaine and heroin polysubstance users: Common and differential effects on separate executive components. *Psychopharmacology*, *190*(4), 517–530. https://doi.org/10.1007/s00213-006-0632-8

Verdich, C., Toubro, S., Buemann, B., Lysgård Madsen, J., Juul Holst, J., & Astrup, A. (2001). The role of postprandial releases of insulin and incretin hormones in meal-induced satiety - Effect of obesity and weight reduction. *International Journal of Obesity*, *25*(8), 1206–1214. https://doi.org/10.1038/sj.ijo.0801655

Vlagsma, T. T., Koerts, J., Tucha, O., Dijkstra, H. T., Duits, A. A., van Laar, T., & Spikman, J. M. (2017). Objective Versus Subjective Measures of Executive Functions: Predictors of Participation and

Quality of Life in Parkinson Disease? *Archives of Physical Medicine and Rehabilitation*, *98*(11), 2181–2187. https://doi.org/10.1016/j.apmr.2017.03.016

Vogels, N., Diepvens, K., & Westerterp-Plantenga, M. S. (2005). Predictors of long-term weight maintenance. *Obesity Research*, *13*(12), 2162–2168. https://doi.org/10.1038/oby.2005.268

Volkow, N. D., Wang, G. J., Fowler, J. S., Tomasi, D., & Baler, R. (2011). Food and drug reward: Overlapping circuits in human obesity and addiction. *Current Topics in Behavioral Neurosciences*, *11*, 1–24. https://doi.org/10.1007/7854_2011_169

Wanmaker, S., Leijdesdorff, S. M. J., Geraerts, E., van de Wetering, B. J. M., Renkema, P. J., & Franken, I. H. A. (2018). The efficacy of a working memory training in substance use patients: A randomized double-blind placebo-controlled clinical trial. *Journal of Clinical and Experimental Neuropsychology*, *40*(5), 473–486. https://doi.org/10.1080/13803395.2017.1372367

Ware, J. E., Snow, K. K., Kosinski, M., & Gandek, B. (1993). SF-36 health survey. *Manual and Interpretation Guide. Boston: The Health Institute, New England Medical Center*, 10–16.

Wasserstein, R. L., & Lazar, N. A. (2016). *The ASA statement on p-values: context, process, and purpose*. Taylor & Francis.

Weir, J. B. de v. (1949). New methods for calculating metabolic rate with special reference to protein metabolism. *The Journal of Physiology*, *109*(1–2), 1.

Whitelock, V., Nouwen, A., Houben, K., van den Akker, O., Rosenthal, M., & Higgs, S. (2018). Does working memory training improve dietary self-care in type 2 diabetes mellitus? Results of a double blind randomised controlled trial. *Diabetes Research and Clinical Practice*, *143*, 204–214. https://doi.org/10.1016/j.diabres.2018.07.005

Will Crescioni, A., Ehrlinger, J., Alquist, J. L., Conlon, K. E., Baumeister, R. F., Schatschneider, C., & Dutton, G. R. (2011). High trait self-control predicts positive health behaviors and success in weight loss. *Journal of Health Psychology*, *16*(5), 750–759.

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. v., & Pennington, B. F. (2005). Validity of the executive function theory of attention-deficit/ hyperactivity disorder: A meta-analytic review. *Biological Psychiatry*, *57*(11), 1336–1346. https://doi.org/10.1016/j.biopsych.2005.02.006

Wingo, J., Kalkut, E., Tuminello, E., Asconape, J., & Han, S. D. (2013). Executive functions, depressive symptoms, and college adjustment in women. *Applied Neuropsychology*, *20*(2), 136–144. https://doi.org/10.1080/09084282.2012.670154

Wing, R. R., & Phelan, S. (2005). Long-term weight loss maintenance. *The American Journal of Clinical Nutrition*, *82*(1 Suppl), 222–225. https://doi.org/10.1093/ajcn/82.1.222S

Withrow, D., & Alter, D. A. (2011). The economic burden of obesity worldwide: A systematic review of the direct costs of obesity. *Obesity Reviews*, *12*(2), 131–141. https://doi.org/10.1111/j.1467-789X.2009.00712.x

World Health Organization. (2000). *Obesity: preventing and managing the global epidemic* (Issue 894). World Health Organization.

Wyckoff, E. P., Evans, B. C., Manasse, S. M., Butryn, M. L., & Forman, E. M. (2017). Executive functioning and dietary intake: Neurocognitive correlates of fruit, vegetable, and saturated fat intake in adults with obesity. *Appetite*, *111*, 79–85. https://doi.org/10.1016/j.appet.2016.12.039

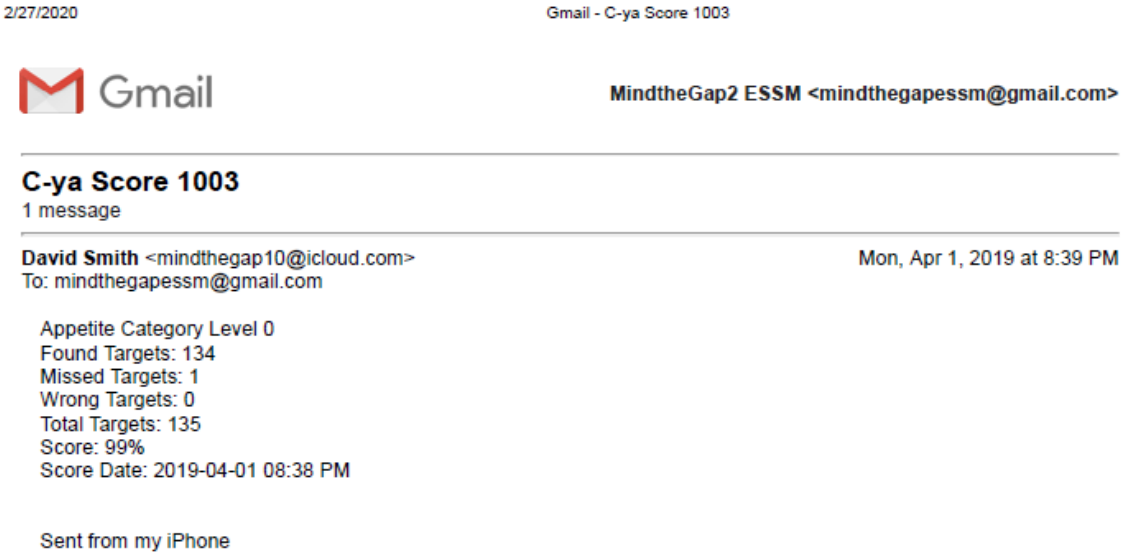
Yang, E. (2017). Bilinguals' working memory (WM) advantage and their dual language practices. *Brain Sciences*, *7*(7), 86. https://doi.org/10.3390/brainsci7070086

Yang, Y., Shields, G. S., Guo, C., & Liu, Y. (2018). Executive function performance in obesity and overweight individuals: A meta-analysis and review. *Neuroscience and Biobehavioral Reviews*, *84*(2), 225–244. https://doi.org/10.1016/j.neubiorev.2017.11.020

Yan, W. sen, Li, Y. H., Xiao, L., Zhu, N., Bechara, A., & Sui, N. (2014). Working memory and affective decision-making in addiction: A neurocognitive comparison between heroin addicts, pathological gamblers and healthy controls. *Drug and Alcohol Dependence*, *134*(1), 194–200. https://doi.org/10.1016/j.drugalcdep.2013.09.027

Zhu, Y., Jiang, H., Su, H., Zhong, N., Li, R., Li, X., Chen, T., Tan, H., Du, J., Xu, D., Yan, H., Xu, D., & Zhao, M. (2018). A newly designed mobile-based computerized cognitive addiction therapy app for the improvement of cognition impairments and risk decision making in methamphetamine use disorder: Randomized controlled trial. *JMIR MHealth and UHealth*, *6*(6), 1–14. https://doi.org/10.2196/10292

Chapter 8 Supplementary Material



2/27/2020 Gmail - C-ya Score 1003

Gmail MindtheGap2 ESSM <mindthegapessm@gmail.com>

C-ya Score 1003
1 message

David Smith <mindthegap10@icloud.com> Mon, Apr 1, 2019 at 8:39 PM
To: mindthegapessm@gmail.com

Appetite Category Level 0
Found Targets: 134
Missed Targets: 1
Wrong Targets: 0
Total Targets: 135
Score: 99%
Score Date: 2019-04-01 08:38 PM

Sent from my iPhone

Figure S1: Image of the results emailed from Curb-Your Addiction (C-Ya©).

8.1 Formative Analysis

Table S1: Measures of Depression, Self-Efficacy and Self-control per group (Median values (IQR); Mean values ± SD)

	Stable	Reduced		
		RED total	RED-R	RED-S
	(n= 6)	*(n= 23)*	*(n= 15)*	*(n= 8)*
Self Efficacy	32 (23-38)	33 (31-37)	33 (31-38)	31 (31-36)
Weight Efficacy	7.2 ± 1.3	7.1 ± 1.1	7.4 ± 1.6	7.0 ± 1.7
BDI	4.5 (0-10)	10 (5-17)	10 (5-15)	12 (4.8-23)
	(n= 5)	*(n= 20)*	*(n= 14)*	*(n= 6)*
Self-Control Scale	3.9 (3.3-4.2)	3.8 (3.4-4.0)	3.7 (3.3-3.9)	3.9 (3.5-4.2)

RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight; BDI: Becks Depression Inventory.

Table S2: Self-reported measures of Activity and Sedentary behaviour per group (Median values (IQR))

	Stable	RED		
		RED total	RED-R	RED-S
	(n= 6)	*(n= 23)*	*(n= 15)*	*(n= 8)*
Activity (min/wk)				
Vigorous	**150** (90-338)	**80** (0-180)	**90** (0-180)	**58** (0-165)
Moderate	**93** (45-244)	**135** (90-210)	**150** (90-300)	**120** (84-175)
Transport	**15** (0-608)	**0** (0-80)	**0** (0-80)	**30** (0-99)
Total activity	**350** (184-1114)	**290** (180-600)	**290** (180-720)	**280** (195-375)
Sedentary (min/wk)	**5460** (2100-5933)	**5040** (3360-5460)	**5040** (2940-5460)	**4620** (3780-6405)

Activity and sedentary behaviour expressed in minutes per week as reported in the Global Physical Activity Questionnaire (GPAQ). RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight.

Table S3: BRIEF-A subscale and summary scale t-scores per group (Median values (IQR))

	Stable	Reduced		
		RED	RED-R	RED-S
	(n= 6)	*(n= 23)*	*(n= 15)*	*(n= 8)*
Inhibit	**47** (42-56)	**51** (46-58)	**51** (46-58)	**54** (45-59)
Shift	**56** (48-57)	**56** (48-57)	**56** (48-57)	**52** (47-66)
Emotional	**42** (41-52)	**55** (50-62)	**55** (50-62)	**57** (46-67)
Self Monitor	**42** (41-55)	**51** (42-59)	**51** (42-55)	**57** (39-60)
Initiate	**53** (43-59)	**47** (44-57)	**47** (41-55)	**50** (47-67)
WM	**53** (455-64)	**56** (46-64)	**53** (46-64)	**57** (42-63)
Plan	**49** (39-63)	**50** (46-61)	**50** (47-58)	**48** (45-64)
Task Monitor	**49** (40-65)	**54** (46-60)	**51** (45-60)	**58** (54-64)
Organization	**44** (39-50)	**51** (43-60)	**48** (43-60)	**54** (38-62)
BRI	**46** (41-53)	**54** (49-62)	**54** (50-56)	**58** (43-65)
MI	**49** (41-62)	**51** (45-56)	**51** (45-54)	**52** (46-60)
GEC	**47** (39-59)	**52** (47-58)	**51** (47-53)	**54** (47-63)

T-Scores ≥ 65 are within clinical range and are indicative of executive dysfunction. RED-R: Recently reduced-obese; RED-S: Stable reduced-obese; Stable: Stable weight; BRI: Behavioural regulation index; MI: Metacognition index; GEC: Global executive composite.

8.2 Intervention Analysis

Table S4: BRIEF-A subscale and summary scale t-scores per time point (Median values (IQR))

	t1 *(n= 19)*	t2 *(n= 19)*	t3 ***(n= 11)***	t1*t2 *(n= 19)*		Repeated ***(n= 11)***	
				z	**p-value**	**χ^2**	**p-value**
Inhibit	**48** (44-55)	**48** (45-61)	**49** (44-59)	-0.421	0.673	0.40	0.819
Shift	**56** (48-57)	**56** (48-61)	**57** (52-65)	-0.236	0.813	1.19	0.552
Emotional	**55** (50-62)	**56** (50-62)	**55** (48-63)	-0.142	0.887	0.05	0.973
Self Monitor	**51** (37-59)	**51** (42-64)	**55** (37-64)	-0.095	0.924	0.96	0.618
Initiate	**47** (44-55)	**54** (41-60)	**55** (47-57)	-0.315	0.752	1.27	0.531
WM	**59** (40-64)	**50** (43-67)	**56** (47-64)	-0.246	0.806	2.39	0.303
Plan	**50** (45-65)	**61** (48-66)	**58** (48-65)	-1.59	0.112	2.88	0.237
Task Monitor	**51** (42-65)	**51** (42-65)	**61** (46-65)	-0.087	0.930	8.27	0.016
Organization	**53** (43-60)	**54** (43-59)	**52** (50-57)	-0.794	0.427	2.25	0.325
BRI	**54** (50-56)	**51** (47-65)	**52** (48-61)	-0.065	0.948	2.39	0.303
MI	**52** (44-61)	**54** (44-65)	**59** (54-61)	-0.728	0.466	5.06	0.080
GEC	**53** (46-63)	**51** (46-68)	**57** (46-60)	-0.19	0.849	0.33	0.850

BRI: Behaviour regulation Index; MI: Metacognition index; GEC: Global executive composite. Median t-scores for baseline (t1), post intervention (t2) and 6-month follow up (t3). t1*t2: Wilcoxon signed rank test used to evaluate differences between baseline and post intervention; Repeated: Friedman test for repeated measures across all three time points.

Table S5: Measures of Eating behaviour per time point (Mean values ± SD; Median values (IQR))

	t1 (n=19)		t2 (n=19)		t3 (n=11)		t1*t2 (n=19)		Repeated (n= 11)	
							t/z	p-value	F/χ^2	p-value
EDE-Q										
Restraint	**3.0**	(1.4-3.8)	**2.4**	(1-3)			-1.767	0.077		
Eating concern	**1.2**	(0.2-1.8)	**0.8**	(0.2-1.6)			-0.798	0.425		
Shape Concern	**3.4**	(1.4-3.9)	**2.5**	(1-3.8)			-1.862	0.063		
Weight Concern	**2.2**	(1-3.4)	**2.4**	(1-2.8)			-1.235	0.217		
Total Score	**2.6**	(1-3.2)	**2.3**	(1-2.8)			-1.972	0.049		
EEQ	**11.7**	±4.3	**11.5**	±4.7	**10.8**	±3.6	0.431	0.672	0.160	0.853

EDE-Q: Eating Disorder Examination Questionnaire; EEQ: Emotional Eater Questionnaire. Mean and median values for baseline (t1), post intervention (t2) and 6-month follow up (t3). t1*t2: Wilcoxon signed rank test used to evaluate differences between baseline and post intervention; Repeated: Friedman test for repeated measures across all three time points.

Table S6: Measures of Self-control, Self-efficacy and Depression per time point (Mean values ± SD; Median values (IQR))

	t1 (n=19)		t2 (n=19)		t3 (n=11)		t1*t2 (n=19)		Repeated (n= 11)	
							t/z	p-value	F/χ^2	p-value
Self-Control Scale	**3.8**	(3.4-4)	**3.7**	(3.1-3.9)	**4.0**	(3.5-4.2)	-0.827	0.408	2.048	0.359
WEL	**7.2**	±1.4	**6.8**	± 1.4	**6.8**	± 1.9	1.128	0.274	1.165	0.332
Self Efficacy	**33.6**	± 4.2	**33.5**	± 3.7	**33.6**	± 2.8	0.076	0.940	0.352	0.707
BDI	**10**	(4-15)	**9**	(6-11)			-0.087	0.930		

WEL: Weight Efficacy Lifestyle Questionnaire; BDI: Becks Depression Inventory. Mean and median values for baseline (t1), post intervention (t2) and 6-month follow up (t3). t1*t2: Wilcoxon signed rank test used to evaluate differences between baseline and post intervention; Repeated: Friedman test for repeated measures across all three time points.

8.3 Methodological Analysis

Table S7: Spearman's correlation between BRIEF-A scales and Digit Span measures.

	fTE_ML	fTE_TT	fML	fMS	bTE_ML	bTE_TT	bML	bMS
BRI								
Inhibit	-0.121	-0.045	0.212	0.114	0.211	0.303	0.122	0.168
Shift	-0.102	-0.002	0.061	-0.159	0.160	0.238	0.081	0.129
Emotional Control	-0.337	-0.312	-0.151	-0.255	-0.001	0.110	-0.158	-0.119
Self Monitor	-0.245	-0.074	0.010	-0.058	0.110	0.113	-0.043	0.039
MI								
Initiate	-0.146	0.046	0.004	-0.126	0.288	0.217	0.148	0.240
WM	-0.135	0.019	0.198	-0.005	0.177	0.208	0.154	0.197
Plan	-0.150	0.047	0.083	-0.090	0.142	0.154	0.199	0.202
Task Monitor	-0.101	0.027	0.154	0.037	0.268	0.208	0.226	0.245
Organization	-0.341	-0.190	0.004	-0.084	-0.073	-0.054	-0.141	-0.141
BRI	-0.290	-0.197	0.008	-0.152	0.108	0.211	-0.031	0.029
MI	-0.221	-0.043	0.093	-0.067	0.146	0.120	0.131	0.166
GEC	-0.224	-0.071	0.106	-0.039	0.187	0.230	0.100	0.145

BRI: Behaviour rating index; MI: Metacognition index; GEC: Global executive composite. The preceding lower case 'f' denotes forward digit span, the preceding lower case 'b' denotes backward digit span. TE_ML: two error max length; TE_TT: two error total trials; ML: max length; MS: mean span.

APPENDIX

APPENDIX 1 – Ethics Clearance Letter

UNIVERSITY OF CAPE TOWN
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20 June 2018

HREC REF: 230/2018

Dr J Kroff
Sport Science Institute
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3rd floor ESSM

Dear Dr Kroff

PROJECT TITLE: THE EFFECT OF WORKING MEMORY TRAINING ON THE POSSIBLE PHYSIOLOGICAL AND BEHAVIOURAL COMPENSATORY RESPONSES TO CONVENTIONAL WEIGHT LOSS: THE MIND THE GAP INTERVENTION STUDY (MTG2)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 June 2019.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Please quote the HREC reference number in all your correspondence.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

APPENDIX 2 – CONSENT FORM

Division of Exercise Science and Sports Medicine

Department of Human Biology

Faculty of Health Sciences

University of Cape Town

P.O. Box 115, Newlands 7725, South Africa

Tel: +27 21 650 4561 Fax: +27 21 650 1796

Head of Division: Professor E V Lambert

PARTICIPANT INFORMATION SHEET AND CONSENT FORM 1

INTERVENTION GROUP

PROJET TITLE: The Effect of Working Memory Training on the Possible Physiological and Behavioural Compensatory Responses to Conventional Weight loss: The Mind the Gap Intervention Study (MTG2)

Dear Volunteer,

We would like to give information about the above-mentioned study, which will be conducted by researchers from the University of Cape Town (UCT)'s Division of Exercise Science and Sports Medicine, Department of Human Biology, Faculty of Health Sciences.

WHY ARE WE DOING THIS STUDY?

We understand that achieving and maintaining a healthy body weight are a concern for many people all over the world. We as researchers are also concerned about the obesity problem, with obesity becoming a major health problem already negatively affecting the lives of more than 55% of women and 30% of men living in South Africa. Furthermore, research shows that 50-80% of obese individuals who have successfully lost weight return to their starting weight within 3-5 years. Scientists have identified several physical (e.g. slower metabolic rate, higher level of hunger gut hormones) and behavioural (e.g. reduction in unplanned physical activity) factors as "compensations" which are triggered by the reduction in body weight, making further weight loss more difficult.

In our previous study very similar to this study, we have recognized that individuals who are successful at weight loss, have attitudes and behaviours which include exercising more, have very strict rules toward their eating habits and regularly weigh themselves to prevent weight regain. They also show that they adhere to the ability to consciously make decisions on a daily basis not to overeat or eat unhealthy foods. Individuals who cannot adhere to this, go back to their old habits and regain the weight that they have lost.

WHAT IS THE STUDY ABOUT?

In this study we will attempt to determine if specific memory training will help a previously overweight individual to keep to specific eating and exercise behaviours that will prevent weight regain. We will try to identify the physiological and behavioural factors that may possibly change over time that could result in either successful weight loss maintenance or weight regain.

WHO CAN TAKE PART IN THIS STUDY?

We are looking for Women between the ages of 25-45 years of age, who are apparently healthy and premenopausal. You may participate if you have done the following: below:

- Reached a BMI > 33 prior to weight loss.
- Lost more than 10% of initial weight or highest adult weight
- Reached goal weight within the last 6 months

The following individuals can unfortunately not take part in the study even if they do fit in the criteria mentioned above:

- Had an initial BMI > 45 prior to weight loss
- Has a BMI >32 after 10% body weight loss/goal weight reached
- Have been diagnosed with an illness causing weight loss but are currently recovered

The following individuals cannot take part in the study even if they fall in any of the 2 categories above:

- Pregnant, lactating or breast feeding
- Irregular menstrual cycle function (defined as less than 7 cycles per year, or cycles with intervals greater then 35 days)
- Any medical condition and/or require chronic medication known to affect energy expenditure (i.e. B2-agonists, Beta-blockers, corticosteroids)
- On medication/supplements for weight loss
- Diagnosed with thyroid dysfunction
- Diagnosed as having an eating disorder (e.g. bulimia or anorexia nervosa) or mental disorder
- Achieving a score indicative of Executive Dysfunction with Behavioural Rating of Executive Function Questionnaire (BRIEF-A)
- Contraindications for MRI (presence of any pin, prosthesis, or any other magnetic materials inside/within their bodies, claustrophobia).

WHAT WILL HAPPEN IF YOU DECIDE TO TAKE PART IN THIS STUDY?

Volunteers will be asked to visit the UCT Division for Exercise and Sports Medicine, based on the 2nd and 3rd floor of the Sports Science Institute of South Africa, in Newlands, on 10 separate occasions for testing over a period of one and a half years. The following will take place at each meeting:

Baseline testing will consist of three laboratory visits and will happen during week 1 to week 4 of the project.

Prior to Day 1

- ***Survey***: You will complete online questionnaires on Survey Monkey. This will determine if you can take part in the study.

VISIT 1 (±2 HOURS IN DURATION)

- ***Informed Consent***: A researcher will explain all the testing procedures to you, after which you will be requested to sign a consent form if you are willing to take part in the study.

- ***Survey Completion*** via 1-on-1 interview: A researcher will interview you about your health, weight loss history, eating habits, physical activity levels, emotional well-being and sleeping habits.

- ***Body Mass Index***: Your weight and height will be measured and your body mass index will be calculated to determine if you are normal or overweight.

- ***Waist and Hip Circumferences***: We will measure your waist and hip circumferences using a spring-loaded tape measure, applied over a light weight T-shirt.

- ***Resting Heart Rate and Blood Pressure***: Systolic and diastolic blood pressure will be measured using an automatic blood pressure monitor. The average of three readings will be considered as your blood pressure. Resting pulse (heart rate) will also be measured by the automatic blood pressure monitor.

- ***Working Memory Performance Tests***: You will be asked to perform two different working memory tests (test 1 and test 2) on a computer. Test 1: You will be asked to remember a sequence of numbers (of increasing increments) flashed on the screen, you will have to recall the sequence by typing it in the appropriate block on the screen. At first sequences will have to be recalled in forward order (e.g. 2, 4, 8, 3 will become 2, 4, 8, 3) as flashed on the screen. With the second trial during the test, the sequence of numbers must be recalled in reverse order (e.g. 2, 4, 8, 3 will become 3, 8, 4, 2). Test 2: You will be asked to recall letters of the alphabet that will be flashed on the screen by clicking on the mouse of the computer if the letter is the same as 1 before (first trial), 2 before (second trial) and 3 before (3rd trial). These tests will determine your short-term memory capacity.

- ***24-Hour Dietary Recall***: You will be asked with the assistance of a registered dietician to complete an online dietary assessment of all the food and beverages that you have consumed during the previous 24-hours. The dietician will guide you on how to complete this assessment using the online tool.

- ***Physical Activity and sleep questionnaire completion***: You will complete a questionnaire about your planned and unplanned exercise frequency (times per week) and

duration and three short questionnaires about your sleep behaviour. This will provide a measure of your physical activity levels and describe your sleepiness index and risk for two major sleep disorders (insomnia and apnoea).

7-day period between Visit 1 and Visit 2

- ***Accelerometry***: You will be fitted with an accelerometer which will measure the number of steps you take per day. We will be able to determine the amount of time you spend performing light, moderate or vigorous physical activity. The device is a small watch-like device without a "face" attached to a waist band that connects with Velcro. The device will be worn with the waist belt over your right hipbone. You will be asked to wear this device on your hip over a full 7-day period for the collection of your physical activity. You will be asked to sleep with the device on your hip, however, if this is too uncomfortable, you may remove the band during sleep time.

- ***Assessment of habitual sleep***: you will be fitted with an actiwatch 2 on the wrist of your non-dominant arm for seven consecutive days (including two non-working days) to objectively measure your sleep patterns. Timing of sleep periods will be established manually based on published guidelines.

These 2 devices are not water proof; therefore, you will be asked to remove the devices during bathing/showering, swimming or any other type of water-based activities.

- ***Dietary recall***: You will be asked to complete two 24-hour Dietary Recall assessments between visit 1 and visit 2. This information will be used to determine your daily and weekly energy intake in kilocalories.

VISIT 2 (±4 HOURS IN DURATION)

- ***Resting Metabolic Rate***: You will be asked to not eat or drink anything (except water) for 10-12 hours prior to my visit. For this test you will be lying down and then be fitted with a canopy (a clear plastic helmet-like device) which will measure the amount of oxygen you consume and carbon dioxide you produce at rest – this can be used to calculate your resting metabolic rate (i.e. the amount of calories you expend per day in a resting state). You will be asked to simply lie down and relax for 20 - 40 minutes.

- ***Body Composition***: Bioelectrical Impedance Analysis (BIA) will be used to measure your body composition, and for this we require that you be in a fasted state. Four small electrodes will be attached to your body (two on the same hand, and two on the same foot) to which four wires will be attached. A very light electrical impulse (so light that you will not feel it) will be sent through your body, and a value will then be recorded. This value represents how well the current passes through your body, and is a good indicator of body fat levels. It does not require undressing and is completely painless and non-invasive.

- ***Standardized meal***: you will be asked to eat a ready-made meal consisting of ~45% calories from fat and 45% of calories from carbohydrate and 10% calories from protein. Prior the meal, one hour and 3 hours after the meal you will be asked to rate the sensation of "fullness" that you attribute to eating these kinds of meals.

- ***Fasting and post-meal Blood Samples***: Prior to consuming a standardized meal, a small tube (cannula) will be inserted into either a blood vessel in your forearm or one in the crook of your elbow. This is necessary to collect blood samples prior to the pre-standarized meal, and 1 hour and 3 hours after initial meal consumption. The blood samples taken will be analysed for hunger and appetite hormones in your blood stream. These markers will be used to determine your appetite in a fasted state and in response to the standardized meal.

- ***Metabolic Response to Standardized Meal***: You will repeat the canopy/plastic hood test whereby oxygen uptake and carbon dioxide production will be measured. This will help us determine your metabolic response to the meal.

- ***Visual Analogue Scales (VAS):*** Four subjective appetite sensations (desire to eat, hunger, fullness and prospective food consumption) will be assessed before and after the your meal ingestion and at 1hour and 3 hours post-ingestion to determine you level of subjective hunger.

- ***Eating Behaviour questionnaire completion***: You will be asked to complete four questionnaires about your eating behaviour. The type of questions that will be asked will focus on your diet restraint and emotional factors towards eating. One of the questionnaires will be a computer-based questionnaire where you have to rate how much you like the taste, or want to eat a specific food by looking at a colour picture of the food item on the screen.

VISIT 3 (±1 HOURS IN DURATION)

- ***Brain Response to food cues***: This assessment will take place at MRI unit of Groote Schuur Hospital, Observatory, Cape Town. The Functional Magnetic Resonance Imaging (MRI) scanner will measure your brain response while you are looking at specific food items. The MRI scanner is a large tunnel-like device with enough space for a human body to be surrounded by the device. You will be asked to lie flat on the MRI bed, while on the bed you will move into the scanner via an operator who monitors you carefully. The MRI procedure itself is harmless, you may only experience physical discomfort due to the enclosed space around you. During the first test in the scanner you will be asked to complete a memory task by clicking on a computer mouse when the letter on the screen is the same as the letter 1-before or 2-before. You will have the computer mouse in your hand. This test will determine the specific area of the brain (for example the reward centre of the brain) that will be activated when food cues are flashed at you. This will provide more information on your behaviour towards food. Prior to entering the scanner, you will also be fitted with three additional electrodes: 1 on each shoulder, and one on the lower left area of your chest or ribcage, that will record your heart rate throughout the test.

- ***Visual Analogue Scales (VAS):*** Four subjective appetite sensations (desire to eat, hunger, fullness and prospective food consumption) will be assessed before and after the fMRI assessment to assess your subjective rating of hunger at the time.

Intervention period: (From week 5 to week 10)

After baseline testing, you will be asked to undergo the working memory training, using a specific iPhone/iPad application (C-Ya app). This app will be downloaded for you on your iPhone/iPad. If you do not have an iPhone or iPad, one will be provided for the duration of the study. You will

complete a 30min session using the application, 4 times a week for a period of 6 weeks. You will be able to complete sessions anytime during the day on your training days. You will start with the easy levels on the application during the first week, and progress to more complex levels as you improve your performance on the preceding levels.

The researcher will explain the different steps of the working memory training programme to you once they have downloaded the application for you. You will also receive a step-by-step information sheet on guidelines how to use the application and complete the training. You will be asked to send your training data result (given to you at the end of each session on the app) to the test administrator by clicking on the "send" option.

Educational programme: You will also be asked to undergo a specific educational programme starting the week after visit 3 and lasting for 6 weeks, before returning for visit 4. You will be asked to listen to a recorded session (45 min talk) on challenges and guidelines to weight loss maintenance by the Principal investigator in the comfort of your home/office at any time during the first week of the 6-week period. Hereafter, you will be given opportunities to ask questions, via telephone or email, regarding the information presented in the talk. You will receive a WhatsApp/SMS message twice a week to stay motivated in your attempt to maintain weight loss. Each whats app will be different in content and will entail words of encouragement and or healthy eating and benefits of exercise advice.

After the intervention you will undergo the post-intervention assessments during week 11 to 13.

VISIT 4 (±2 HOUR IN DURATION):

You will undergo height, weight, BMI, waist circumference and hip circumference measurement as in visit 1 prior to the intervention. You will also undergo resting heart rate and blood pressure measurements and will you be asked to complete the working memory performance test, 24-Hour Dietary Recall, sleep and physical activity questionnaire completion.

Between visit 4 and visit 5, you will be asked to complete two more 24-Hour Dietary recalls.

VISIT 5 (±4 HOURS IN DURATION):

Visit 5 will be a repeat of visit 2. The following procedures will be repeated: Resting Metabolic Rate, ingestion of standardized meal, Fasting and post-meal Blood Samples, metabolic response to standardized meal, eating behaviour questionnaire completion.

VISIT 6 (±1 HOUR IN DURATION)

You will be asked to undergo a repeat of the brain response to food cues assessment at Groote Schuur hospital.

After completion of the Post-intervention visits, you will be asked to continue your endeavours and lifestyle as is for the following six months. After six months you will be contacted via email and telephone to take part in the 6 months follow-up assessments.

Long-term Data Collection (week 37 to 61) - Optional

Six months after the 6-week study period, we will contact you by email or telephonically to ask if you would be willing to complete 3 more visits to the laboratory on 3 separate days. Following

the six month set of visits, you will also be asked to visit the laboratory one more time at 12-months after the 6-week study period.

6 months Post-Intervention: During week 37 to week 39 of the project, you will visit the lab on three separate days (visit 7, 8 and 9). During these visits the same data collection, tests and order of assessments will be conducted as during visit 4, 5 and 6. This will determine if any changes in the outcomes post-intervention will still be present at 6 months after training/educational programme was ceased.

12 months Post-Intervention: During week 61 of the project, you will be asked to visit the lab on one occasion (visit 10). During this visit you will be asked to complete height, weight, BMI, Waist circumference, Hip Circumferences, resting Heart Rate, blood pressure and body composition measures. You will repeat the Working Memory Performance tests, the resting metabolic rate test, fasting blood tests and all dietary analyses (24-Hour Dietary recall), eating behaviour questionnaires, physical activity and sleep questionnaires and 7-day physical activity measurement with an accelerometer and 7-day sleep patterns with an actiwatch. On the 8th day following visit 10, the test administrator will collect the accelerometer, actiwatch and dietary recall from your office/home.

WHAT ARE THE RISKS AND DISCOMFORTS OF THIS STUDY?

The potential risks associated with the technique that will be used to collect blood from veins in your arms (i.e. cannulation) in this study are: infection, delayed healing, hematoma, physical pain, mental discomfort and injury to a nerve or vessel. These risks are small and will be minimized by the use of individuals trained to take blood samples, use of sterile techniques and the use of disposable, single-use materials.

If you are claustrophobic or have difficulty spending time in confined spaces, you may experience mild discomfort during the ventilated hood (in laboratory) and fMRI tests (at Groote Schuur Hospital). These trials will be conducted and supervised by fully trained researchers, and any uneasiness will be immediately attended to making you feel as comfortable as possible.

Some risks associated with your participation in computer-based Working Memory Performance Tests and computer-based Food Item Rating and Choice Test will be hesitance and uncertainty regarding the answers and operation of the keyboard commands. The researcher will ensure that you are fully familiarized with the keyboard commands by letting you complete practice trials prior to the "real" test until you are comfortable in how to operate and complete the commands. You will also be allowed, if you are not comfortable with a question, to skip the question on the screen and proceed to the next step.

Other small discomforts include an unpleasant taste in your mouth during the premade meal ingestion. You may experience discomfort during the anthropometric measurements when you will be asked to appear in minimal clothing for your weight measurement, however, an alternative method can be followed if you do not want to stand on the scale in minimal clothing.

You may experience minimal discomfort from wearing the accelerometer device on right hip especially during sleep and during change of clothing. You will be free to sleep without the

accelerometer on if it does cause discomfort and interfere with your normal activity. There is no risk associated with using the actiwatch to measure sleep habits.

The only other risks may be those associated with completing questionnaires which may ask probing questions about dieting history or attitudes toward food. Researchers will make every effort to treat all volunteers respectfully and with empathy. You are not required to answer any questions which may make you feel uncomfortable.

The researchers are aware that undergoing ten different categories of assessments (laboratory visits) and a working memory training intervention, does cause respondent burden and inconvenience of time. You will be well informed prior to your participation regarding the length of the study, the duration of visits and specific instructions to adhere to prior to the day of testing. If, at any point, you feel you are no longer prepared to tolerate the administrative and time-related constraints of this study, you are free to withdraw.

ARE THERE ANY BENEFITS TO YOU FOR BEING IN THIS STUDY?

Through participating in this study you will gain valuable information about your general health, body composition, eating behaviour, exercise and sleep behaviours, resting metabolic rate, metabolic rate in response to high-fat intake, brain activity in response to food, and psychological and sleep characteristics. You will receive the overall compiled results of the study in a comprehensive final report. The information that you will receive in your report includes health and behaviour outcomes that equates to a value of R10 000 if you would have had this tested commercially.

You will receive remuneration of R50 for your travel cost to and from the laboratory with every visit. This will be paid cash to you on the day of your visits.

During the long-term data collection (after 6 months and after 12 months post intervention), you will be encouraged to keep to your regular eating and physical activity regime. You will receive a voucher allowing you to attend evening talks related to health topics at the Sport Science Institute of South Africa. You will also receive a voucher to visit the laboratory for a weigh-in and body fat calculation session free of charge. You will receive these vouchers once every two months during the 12-month period starting at the end of the 8-week study and ending with visit 10.

WHAT ARE THE OTHER ETHICAL CONSIDERATIONS?

The University of Cape Town's Faculty of Health Sciences Human Research Ethics Committee (contact information below) has approved this study. The study will be performed in accordance with the principles of the Declaration of Helsinki (2013, Fortaleza, Brazil), International Conference on Harmonisation and the European Good Clinical Practice (GCP) guidelines, the South African GCP guidelines, and the laws of South Africa. The study will be covered by the University of Cape Town's no-fault insurance policy (more details below).

You will not be included in the study unless you have signed a consent form, after the investigator has provided substantial verbal and written explanation of the study, including risk factors. Participation in the study is entirely voluntary and you have the right to withdraw from the study at any time without stating a reason. The investigator may also withdraw you from the study at

any time. All records and results generated from this study will be stored in a password-protected computer database to ensure your confidentiality and your information will not be passed on to any other parties. You will remain anonymous in any publication resulting from this study.

WHAT HAPPENS IF I GET HURT TAKING PART IN THIS STUDY?

This research study is covered by an insurance policy taken out by the University of Cape Town if you suffer a bodily injury because you are taking part in the study. The insurer will pay for all reasonable medical costs required to treat your bodily injury, according to the SA Good Clinical Practice Guidelines 2006 (or latest version), which are based on the Association of the British Pharmaceutical Industry Guidelines. The insurer will pay without you having to prove that the research was responsible for your bodily injury. You may ask the study doctor for a copy of these guidelines.

The insurer will not pay for harm if, during the study, you:

- Use medicines or other substances that are not allowed
- Do not follow the study doctor's instructions
- Do not tell the study doctor that you have a bad side effect from the exercise
- Do not take reasonable care of yourself

If you are harmed and the insurer pays for the necessary medical costs, usually you will be asked to accept that insurance payment as full settlement of the claim for medical costs. However, accepting this offer of insurance cover does not mean you give up your right to make a separate claim for other losses based on negligence, in a South African court. It is important to follow the instructions of the study investigator, medical doctors and biokineticists and to report straightaway if you have become injured as a result of participation in this study.

WHO DO I SPEAK TO (OR CONTACT) IF I HAVE ANY QUESTIONS ABOUT THE STUDY

Should you have any ethical concerns or questions about the study, please contact the Human Research Ethics Committee:

Prof Marc Blockman	Faculty of Health Sciences – Human Research Ethics Committee Room E53-46, Old Main Building, Groote Schuur Hospital Observatory, 7925	Tel: (021) 406 6338 Fax: (021) 406 6441 Email: nosi.tsama@uct.ac.za

Should you have any queries directly related to the study itself, please contact any of the investigators:

Principal Investigator:

Dr Jacolene Kroff	Division of Exercise Science and Sports Medicine, Department of Human Biology, Faculty of Health Sciences, University of Cape Town	Tel: 021 650 5126 jacolene.kroff@uct.ac.za

Co-Investigators:

Trinity Rudner	Co-Investigator & Study administrator	rudnertrinity@gmail.com 0838610333
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Samantha Brooks	Co-Investigator	drsamanthabrooks@gmail.com 079 031 1967
Louise Clamp	Co-Investigator & Registered Dietician	louiseclamp@btinternet.com 021 650 3108
David John Hume	Co-Investigator	davidjohnhume@gmail.com 021 650 3108
Estelle V Lambert	Co-Investigator	vicki.lambert@uct.ac.za 021 650 3108

CONSENT FORM

I, the undersigned, have been fully informed about the study entitled "The Effect of Working Memory Training on the Possible Physiological and Behavioural Compensatory Responses to Conventional Weight loss: The Mind the Gap Intervention Study (MTG2)" to be conducted by researchers from the Division of Exercise Science and Sports Medicine within the Department of Human Biology, Faculty of Health Sciences at the University of Cape Town.

- I agree to complete questionnaires disclosing my personal details and information relating to my medical, health, sleep and physical activity habits and eating behaviour.
- I understand that I will undergo working memory performance and food choice tests that will require focus and concentration.
- I understand that I will undergo a resting metabolic rate test under a ventilated plastic hood, and a brain response to food cue test inside an MRI scanner, that may cause me to feel uncomfortable in an enclosed space.
- I understand that I will be asked to ingest a 45% carbohydrate, 45% fat and 10% protein meal to test how satisfied I feel after ingesting this type of meal.
- I understand that I will be asked to wear a device on my hip for a period of seven days to determine my level of every-day physical activity and a watch also for seven days to determine my sleep habits.
- I understand that I will be required to complete dietary intake recordings, 3 x 24hour dietary recalls with the help of a dietician.
- I understand that I will be required to undergo a working memory training program using a iPhone/iPad Application, 4 times per week for 6 weeks.
- I understand that I will be required to undergo an educational programme which include listening to a health talk on weight loss maintenance once off and receiving health messages twice per week over a period of 6 weeks.
- I understand that my data, and blood samples will be stored anonymously and my details only identifiable by a unique code that only the principle investigator of this study knows.
- If any of the blood I have provided for this research project is unused or left over when the research is completed (tick ONE choice from each of the following boxes):

  - o I do not give permission for my blood samples to be stored for future research.

AND

I give permission for my blood samples to be stored indefinitely and used in future research of any type, which has been approved by a registered or accredited HREC.

  - o I want my identity removed from my blood and muscle samples.
  - o I want my identity kept with my blood and muscle samples.

- If any of the data I have provided for this research project may be used again for future studies (tick ONE choice from each of the following boxes)
    - I give permission to the Principal Investigator to contact me to ask permission
    - I do not give permission and do not want my data to be used in future research

I have read the information, or it has been read to me. I have had the chance to ask questions about it and I am satisfied with the answers I was given. I consent voluntarily and understand that I have the right to withdraw my consent without this affecting the research I am currently taking part in or my medical care. I have been informed about the risks involved in participating in this study. I understand that my personal details will be treated confidentially. I understand that I may (i) ask the investigator any questions about the tests and results of the study and (ii) withdraw from this study at any time without stating any reason. I also understand that the investigator may withdraw me from this study at any stage. I understand that I will receive general feedback regarding my personal results and that I will not be remunerated for participating in this study. I agree to participate in the study.

PARTICIPANT

FULL NAME_____**SIGNATURE**_____**DATE**_____

INVESTIGATOR

FULL NAME_____**SIGNATURE**_____**DATE**_____

APPENDIX 3 – SCREENING (ONLINE FORM)

UCT Mind the Gap Study Criteria Screening

The following information will allow us to determine whether you meet the criteria to be included as a participant in this study

1.Name: _____

2. Surname: _____

3. Are you aged between 25 and 45 years*
- Yes
- No

4. Did you reach a BMI > 33 before weight loss?*
- Yes
- No

5. Have you lost more than 10% of your initial weight or highest adult weight?*
- Yes
- No

6. Did you reach your goal weight within the last 6 months?
- Yes
- No

7. If not in the last 6 months, how long ago (number of months) did you reach your goal weight?_____

Are you currently:

8. Pregnant
- Yes
- No

9. Breastfeeding
- Yes
- No

10. Experiencing irregular menstrual cycle function (defined as less than 7 cycles per year or cycles with intervals greater then 35 days)
- yes
- No

11. What is your Date of Birth: _____

12. How old are you?_____

13. Your height in cm (if known)? _____

14. Your current weight in kg (if known)? _____

15. Your heaviest weight in kg (if known)? _____

16. Do you suffer from/have you ever been diagnosed with a metabolic disease?
- Yes
- No

17. Do you suffer from/have you ever been diagnosed with any other chronic condition?
- Yes
- No

18. Do you suffer from/have you ever been diagnosed with thyroid dysfunction?
- Yes
- No

19. Do you take any chronic medication (for example: High blood pressure medications, asthma medications, statins and/or diabetic medications etc.)?
- Yes
- No

20. Do you take chronic medication known to affect energy expenditure (i.e. B2-agonists, Beta-blockers, corticosteroids)
- Yes
- No

21. Do you currently take any medications/supplements for weight loss?
- Yes
- No

22. Do you suffer from/have you ever been diagnosed with a eating disorder (for example bulimia, anorexia nervosa)?
- Yes
- No

APPENDIX 4 – MEDICAL SCREENING (ONLINE FORM)

Medical History: Family

Where applicable please answer which of your first degree relatives (mother/father/brother/sister) have presented with the following (please also indicate the year of the event/diagnosis):

* Required

Before starting the questionnaire, please enter your participant code: *_____

1a. Has anyone from your immediate family (mother/father/brother/sister) suffered from a stroke? *
- Yes
- No

1b. If yes please indicate who and in what year it occurred?_____

2a. Has anyone from your immediate family (mother/father/brother/sister) suffered from diabetes? *
- Yes
- No

2b. If yes, please indicate who and in what year it occurred?_____

3a. Has anyone of your immediate family (mother/father/brother/sister) suffered from obesity? *
- Yes
- No

3b. If yes, please indicate who and for how many years (approximately) they have been Obese_____

4a. Has anyone of your immediate family (mother/father/brother/sister) suffered from high cholesterol? *
- Yes
- No

4b. If yes, please indicate who and for how many years (approximately) they have had high cholesterol._____

10. **5a. Has anyone of your immediate family (mother/father/brother/sister) suffered from high blood pressure? ***
- Yes
- No

5b. If yes, please indicate who and in what year it occurred?_____

6a. Has anyone of your immediate family (mother/father/brother/sister) suffered from Cancer? *
- Yes
- No

6b. If yes, please indicate who and in what year it occurred?_____

7a. Has anyone of your immediate family (mother/father/brother/sister) suffered from a

Heart attack? *
- Yes
- No

7b. If yes, please indicate who and in what year it occurred?_____
8a. Has anyone of your immediate family (mother/father/brother/sister) suffered from other heart conditions? *
- Yes
- No

8b. If yes, please indicate the condition, which family member in particular and in what year it occurred?_____
18. **9a. Has anyone of your immediate family (mother/father/brother/sister) suffered from Angina (Heart pains)?** *
- Yes
- No

9b. If yes, please indicate who and in what year it occurred?_____
10a. Has anyone of your immediate family (mother/father/brother/sister) undergone Bypass surgery? *
- Yes
- No

10b. If yes, please indicate who and in what year it occurred?_____
11a. Has anyone from your immediate family (mother/father/brother/sister) suffered from Peripheral cardiovascular disease (of the veins in the arms and legs)? *
- Yes
- No

11b. If yes, please indicate who and in what year it occurred?_____
12a. Has anyone of your immediate family (mother/father/brother/sister) suffered from Coronary artery disease? *
- Yes
- No

12b. If yes, please indicate who and in what year it occurred?_____
13a. Have any of your immediate family (mother/father/brother/sister) suffered a sudden cardiac death at younger than 60 years of age (due to natural causes) *
- Yes
- No

13b. If yes, please indicate who and in what year it occurred?_____
14a. Has anyone of your immediate family (mother/father/brother/sister) suffered from a condition not mentioned? *
- Yes
- No

14b. If yes, please indicate the condition, which member in particular and in what year it occurred?_____

Medical History: Self

1a. Have you ever suffered from a stroke *
- Yes
- No

1b. If yes, please indicate in what year this occurred?_____
2a. Have you ever been diagnosed with diabetes? *
- Yes
- No

2b. If yes, please indicate in what year you were diagnosed?_____
3a. Have you ever been diagnosed with obesity? *
- Yes
- No

3b. If yes, please indicate in what year you were diagnosed?_____
4a. Have you ever been diagnosed with high cholesterol? *
- Yes
- No

4b. If yes, please indicate in what year you were diagnosed?_____
5a. Have you ever been diagnosed with high blood pressure? *
- Yes
- No

5b. If yes, please indicate in what year you were diagnosed?_____
6a. Have you ever been diagnosed with cancer? *
- Yes
- No

6b. If yes, please indicate in what year you were diagnosed?_____
7a. Have you ever suffered a heart attack? *
- Yes
- No

7b. If yes, please indicate in what year the attack occurred?_____
8a. Do you or have you suffered from any other heart conditions? *
- Yes
- No

8b. If yes, please indicate the condition and in what year it occurred?_____
9a. Have you ever suffered from Angina (heart pains)? *
- Yes
- No

9b. If yes, please indicate in what year it occurred?_____
10a. Have you undergone Bypass surgery? *
- Yes
- No

10b. If yes, please indicate in what year you underwent surgery?_____
11a. Have you ever suffered from Peripheral cardiovascular disease? *
- Yes
- No

11b. If yes, please indicate in what year it occurred?_____
12a. Have you ever suffered from coronary artery disease? *
- Yes
- No

12b. If yes, please indicate in what year it occurred?_____
13a. Have you suffered from a condition not mentioned above? *
- Yes
- No

13b. If yes, please indicate what condition and in what year it occurred?_____

Reproductive History

1. How old were you when you had your first period? *_____
2. Have you ever had a hysterectomy (removal of the uterus)? *
- Yes
- No

3. Have you reached menopause? *
- Yes
- No

4. Number of pregnancies *_____
5. Number of children you have breastfed *_____
6. Are you lactating (i.e. are your breasts producing milk)? *
- Yes
- No

7. Are you using contraception? *
- Yes
- No

8. If yes, what form of contraceptive are you using?_____
9. For how long have you been using these contraceptives... years?_____
10. Have you used other forms of contraception in the past? *
- Yes

- No

11. What forms and for how long did you use these other forms of contraception (years)?_____

APPENDIX 5 – MEDICATION SCREENING (ONLINE FORM)

Medications, Supplements and Cardiac Risk Factors

* Required

Before starting the questionnaire, please enter your participant code *_____

1. Please list ALL the medications you are currently taking as well as the number of years you have taken them (i.e. high blood pressure medication 3 years). Answer 'none' if you are not taking any medication. * _____

2. Please list ALL supplements you are currently taking as well as the number years you have taken them (i.e Whey protein 2 years; Creatine 2 years). Answer 'none' if you are not taking any supplements. *_____

Do you ever experience any of the following:

3. Chest wheezing *
- Yes
- No

4. Chest pain *
- Yes
- No

5. Syncope/dizziness *
- Yes
- No

6. Heart palpitations *
- Yes
- No

7. Chronic fatigue syndrome (feeling tired for extended periods) *
- Yes
- No

8. Muscle cramps *
- Yes
- No

9. Asthma *
- Yes
- No

10. Any other symptoms not listed, if yes, please describe your symptoms below.

_____

APPENDIX 6 – SF36 Health Survey (ONLINE FORM)

General Health Survey

* Required

Before starting the questionnaire, please enter your participant code: *_____

Question 1: In general, how would you describe your health? *
- Excellent
- Very Good
- Good
- Fair
- Poor

Question 2: Compared to 1 year ago, how would you rate your health now? *
- Much better now than a year ago
- Somewhat better now than a year ago
- About the same as a year ago
- Somewhat worse than a year ago
- Much worse than a year ago

Question 3: On a typical day, does your health ever limit you in vigorous activities such as running, lifting heavy objects, or strenuous sports? *
- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Question 4: On a typical day, does your health ever limit you in moderate activities such as moving a table, household chores, or playing golf? *
- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Question 5: On a typical day, does your health ever limit you in lifting/carrying groceries? *
- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Question 6: On a typical day, does your health ever limit you in climbing MORE THAN ONE flight of stairs? *
- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Question 7: On a typical day, does your health ever limit you in climbing ONE flight of stairs? *
- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Question 8: On a typical day, does your health ever limit you in bending or kneeling? *
- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Question 9: On a typical day, does your health ever limit you in walking MORE THAN ONE kilometre? *
- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Question 10: On a typical day, does your health ever limit you in walking MORE THAN ONE block? *
- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Question 11: On a typical day, does your health ever limit you in walking ONE block? *
- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Question 12: On a typical day, does your health ever limit you in bathing or dressing yourself? *
- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Question 13: Over the past 4 WEEKS, has your PHYSICAL health caused you to cut down on the amount of time you spend on work or other activities? *
- No
- Yes

Question 14: Over the past 4 WEEKS, has your PHYSICAL health caused you to accomplish less work than you would have liked? *

- No
- Yes

Question 15: Over the past 4 WEEKS, has your PHYSICAL health caused you to limit the KIND of activities you are able to participate in? *

- No
- Yes

Question 16: Over the past 4 WEEKS, has your PHYSICAL health caused you to experience difficulty performing your usual activities? (e.g. it took longer than usual to do what you had planned). *

- No
- Yes

Question 17: Over the past 4 WEEKS, has your EMOTIONAL health caused you to cut down on the AMOUNT OF TIME you spend on work or other activities? *

- No
- Yes

Question 18: Over the past 4 WEEKS, has your EMOTIONAL health caused you to accomplish less than you would have liked? *

- No
- Yes

Question 19: Over the past 4 WEEKS, has your EMOTIONAL health caused you to do work or other activities less carefully than usual? *

- No
- Yes

Question 20: To what extent have your physical OR emotional problems affected your social life over the past 4 weeks? *

- None
- A little
- A moderate amount
- Quite a bit
- Extremely

Question 21: How much bodily pain have you experienced over the past 4 weeks? *

- None
- A little
- A moderate amount
- Quite a bit
- Extremely

Question 22: If applicable, how much has this pain interfered with your normal work? *

- None
- A little
- A moderate amount
- Quite a bit
- Extremely

Question 23: How often have you felt CHEERFUL over the past 4 weeks? *

- All of the time
- Most of the time
- A good bit of the time
- Some of the time
- A little of the time
- None of the time

Question 24: How often have you felt NERVOUS over the past 4 weeks? *

- All of the time
- Most of the time
- A good bit of the time
- Some of the time
- A little of the time
- None of the time

Question 25: How often have you felt DOWN IN THE DUMPS over the past 4 weeks? *

- All of the time
- Most of the time

- A good bit of the time
- Some of the time
- A little of the time
- None of the time

Question 26: How often have you felt CALM/PEACEFUL over the past 4 wks? *

- All of the time
- Most of the time
- A good bit of the time
- Some of the time
- A little of the time
- None of the time

Question 27: How often have you felt ENERGETIC over the past 4 weeks? *

- All of the time
- Most of the time
- A good bit of the time
- Some of the time
- A little of the time
- None of the time

Question 28: How often have you felt DISHEARTENED over the past 4 wks? *

- All of the time
- Most of the time
- A good bit of the time
- Some of the time
- A little of the time
- None of the time

Question 29: How often have you felt WORN OUT over the past 4 weeks? *

- All of the time
- Most of the time
- A good bit of the time
- Some of the time
- A little of the time
- None of the time

Question 30: How often have you felt HAPPY over the past 4 weeks? *

- All of the time
- Most of the time
- A good bit of the time
- Some of the time
- A little of the time
- None of the time

Question 31: How often have you felt TIRED over the past 4 weeks? *

- All of the time
- Most of the time
- A good bit of the time
- Some of the time
- A little of the time
- None of the time

Question 32: Over the past 4 weeks, how OFTEN has your physical OR emotional health interfered with your social activities? *

- All of the time
- Most of the time
- A good bit of the time
- Some of the time
- A little of the time
- None of the time

Question 33: How true is the following about you? "I get sick easier than others." *

- Definitely true
- Mostly true
- Don't know
- Mostly false

- Definitely false

Question 34: How true is the following about you? "I am as healthy as anybody I know." *

- Definitely true
- Mostly true
- Don't know
- Mostly false
- Definitely false

Question 35: How true is the following about you? "I expect my health to get worse in the future." *

- Definitely true
- Mostly true
- Don't know
- Mostly false
- Definitely false

Question 36: How true is the following about you? "My health is excellent." *

- Definitely true
- Mostly true
- Don't know
- Mostly false
- Definitely false

APPENDIX 7 – DEMOGRAPHIC (ONLINE FORM)

Basic Demographic Information

* Required

1. **Before starting the questionnaire, please enter your participant code *____**
2. **Please identify your marital status: ***
   - Single
   - Married
   - Divorced
   - Widowed
3. **Please indicate your highest level of education achieved: ***
   - High school
   - Matric
   - Diploma
   - Undergraduate degree
   - Postgraduate degree
4. **Please identify your occupation: ***
5. **What is the nature of your work? ***
   - Unemployed
   - Agriculture
   - Mining/quarrying
   - Manufacturing
   - Construction
   - Transport
   - Trade
   - Services
   - Education
   - Health
   - Administration
   - Management
   - Student
   - Other
6. **Please select your monthly income bracket: ***
   - No income

- R1 - R2499
- R2500 - R4999
- R5000 - R7499
- R7500 - R9999
- R10 000 or more

7. **Do you receive supplementary financial support or funding? ***
   - No additional income
   - Government
   - Spouse
   - Friend
   - Family
8. **Which of these best describes your living arrangements? ***
   - Studio apartment
   - 1 bedroom dwelling
   - 2 bedroom dwelling
   - 3 bedroom dwelling
   - 4 bedroom dwelling
   - 5 or more bedroom dwelling
9. **How many housemates or flatmates do you have? ***_____

10. **Do you own a car? ***
    - No car
    - 1 car
    - 2 cars
    - 3 or more cars
11. **Do you own a cell phone?**
    - Yes
    - No

APPENDIX 8 – WEIGHT LOSS SCREENING (ONLINE FORM)

Dieting and Weight Loss History

Exclude any weight fluctuations in the last 5 years due to pregnancy , surgery, illness, medications or other diet-related factors

* Required

**Before starting the questionnaire, please enter your participant code: ***_____

**1. What has been your lowest adult weight? ***_____
2. What has been your highest adult weight?*_____
**3. What was your age at your highest adult weight? ***_____
4. Have you lost weight in the past 6 months? *
   - Yes
   - No

5. If you answered yes to the previous question, how much weight (kg) did you lose?_____

6. Have you lost weight in the past 12 months? *
   - Yes
   - No

7. If you answered yes to the previous question, how much weight (kg) did you lose?_____

8. Has your weight changed more than 2 - 4kg over the past 5 years? *
   - Yes
   - No

9. How many times in the past five years have you lost and then regained weight?

This section is for weight loss participants. If the questions do not apply to you (steady weight

participants) you can skip the following questions and submit.

9a. Number of times weight lost?____

9b. Number of times weight regained?_____

9c. Kilograms gained more than starting weight?_____

9d. Please indicate your weight loss methods (tick all that apply)

- Self-monitored dieting
- Self-initiated exercise
- Self-initiated dieting and exercise
- Group-based dieting
- psychological counseling
- Over-the-counter products
- Prescription medications
- Surgery
- Other...

APPENDIX 9 – GENERAL SELF EFFICICY (ONLINE FORM)

General Self-Efficacy Questionnaire

* Required

1. **Before starting the questionnaire, please enter your participant code: ***_____

Answer the next 10 questions in terms of how much the statements describe YOU.

Question 1: I always manage to solve problems if I try hard enough. *

- Definitely not
- Disagree slightly
- Agree slightly
- Exactly true

Question 2: If someone opposes me, I can find the means and ways to get what I want. *

- Definitely not
- Disagree slightly
- Agree slightly
- Exactly true

Question 3: It is easy for me to stick to my aims and accomplish my goals. *

- Definitely not
- Disagree slightly
- Agree slightly
- Exactly true

Question 4: I am confident that I could deal well with unexpected events. *

- Definitely not
- Disagree slightly
- Agree slightly
- Exactly true

Question 5: Thanks to my resourcefulness, I know how to handle unforeseen situations *

- Definitely not
- Disagree slightly
- Agree slightly
- Exactly true

Question 6: I can solve most problems if I invest the necessary effort. *

- Definitely not
- Disagree slightly
- Agree slightly
- Exactly true

Question 7: I can remain calm when facing difficulties because I can rely on my coping abilities *

- Definitely not

- Disagree slightly
- Agree slightly
- Exactly true

Question 8: When I am confronted with a problem, I can usually find several solutions. *
- Definitely not
- Disagree slightly
- Agree slightly
- Exactly true

Question 9: If I am in trouble, I can usually think of a solution *
- Definitely not
- Disagree slightly
- Agree slightly
- Exactly true

Question 10: I can usually handle whatever comes my way. *
- Definitely not
- Disagree slightly
- Agree slightly
- Exactly true

APPENDIX 10 – WEIGHT EFFICACY LIFESTYLE QUESTIONNAIRE (ONLINE FORM)

Weight Efficacy Lifestyle Questionnaire

* Required

1. **Before starting the questionnaire, please enter your participant code:** *_____

Answer the next 20 questions, rating your level of confidence for each activity/item.

Question 1: I can resist eating when I am anxious or nervous. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 2: I can control my eating over the weekends. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 3: I can resist even if I have to say "no" to others. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 4: I can resist eating when I feel physically "run down." *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 5: I can resist eating when I am watching TV. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 6: I can resist eating when I am depressed/down. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 7: I can resist eating when there are different kinds of foods available (e.g. a buffet). *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 8: I can resist eating when it is impolite to refuse a 2nd helping. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 9: I can resist eating when I have a headache. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 10: I can resist eating when I am reading. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 11: I can resist eating when I am angry or irritated. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 12: I can resist eating when I am at a party. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 13: I can resist eating when others expect me to eat. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 14: I can resist eating when I am in pain. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 15: I can resist eating just before I go to bed. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 16: I can resist eating when there is an unexpected failure in my life. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 17: I can resist eating when high calorie foods are available. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 18: I can resist eating when I think others will be upset if I don't. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 19: I can resist eating when I am uncomfortable. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

Question 20: I can resist eating when I am happy. *

Not confident- (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) -Very Confident

APPENDIX 11 – BECKS DEPRESSION INVENTORY (ONLINE FORM)

Beck Depression Inventory

**Before starting the questionnaire, please enter your participant code: ***_____

Answer the following questions by responding to how you experience the feelings and emotions identified.

Question 1: SADNESS *
- I do not feel sad
- I feel sad much of the time
- I am sad all of the time
- I am so sad and unhappy I can't stand it

Question 2: PESSIMISM *
- I am not discouraged about my future
- I feel more discouraged about my future than I used to be
- I do not expect things to work out for me
- I feel my future is hopeless and will only get worse

Question 3: FAILURE *
- I do not feel like a failure
- I have failed more than I should have
- As I look back, I see a lot of failures
- I feel like I am a total failure as a person

Question 4: LOSS OF PLEASURE *
- I get as much pleasure as I ever did from the things that I enjoy
- I don't enjoy things as much as I used to
- I get very little pleasure from the things I used to enjoy
- I can't get any pleasure from the things I used to enjoy

Question 5: GUILT *
- I do not feel particularly guilty
- I feel guilty over many things I have done or should have done
- I feel quite guilty most of the time
- I feel guilty all of the time

Question 6: PUNISHMENT *
- I do not feel I am being punished
- I feel I may be punished
- I expect to be punished
- I feel I am being punished

Question 7: SELF DISLIKE *
- I feel the same about myself as ever
- I have lost confidence in myself
- I am disappointed in myself
- I dislike myself

Question 8: SELF CRITICALNESS *
- I do not criticize or blame myself more than usual
- I am more critical of myself than I used to be
- I criticize myself for all of my faults
- I blame myself for everything bad that happens

Question 9: SUICIDAL THOUGHTS *
- I do not have any thought of killing myself
- I have thoughts of killing myself, but I would never carry them out
- I would like to kill myself
- I would kill myself if I had the chance

Question 10: CRYING *
- I do not cry any more than I used to
- I cry more than I used to
- I cry over every little thing
- I feel like crying, but I can't

Question 11: AGITATION *
- I am no more restless or wound up than usual
- I feel more restless or wound up than usual
- I am so restless or agitated that it's hard to stay still
- I am so restless or agitated that I have to keep moving or doing something

Question 12: LOSS OF INTEREST IN LIFE *
- I have not lost interest in other people or activities
- I am less interested in other people or things than before
- I have lost most of my interest in other people or things
- It's hard to get interested in anything

Question 13: INDECISIVENESS *
- I make decisions about as well as I ever have
- I find it more difficult to make decisions than usual
- I have much greater difficulty in making decisions than I used to
- I have trouble making any kind of decision

Question 14: SELF WORTHLESSNESS *
- I do not feel like I am worthless
- I do not consider myself as worthwhile and useful as I used to
- I feel more worthless as compared to other people
- I feel utterly worthless

Question 15: LOSS OF ENERGY *
- I have as much energy as ever
- I have less energy than I used to have
- I do not have enough energy to do very much
- I do not have enough energy to do anything at all

Question 16: CHANGES IN SLEEPING PATTERN *
- I have not experienced any change in my sleeping pattern
- I sleep somewhat more than usual
- I sleep somewhat less than usual
- I sleep a lot more than usual
- I sleep a lot less than usual
- I sleep most of the day
- I wake up 1 to 2 hours early and can't get back to sleep

Question 17: IRRITABILITY *
- I am no more irritable than usual
- I am more irritable than usual
- I am much more irritable than usual
- I am irritable all of the time

Question 18: CHANGES IN APPETITE *
- I have not experienced any change in my appetite
- My appetite is somewhat less than usual
- My appetite is somewhat greater than usual
- My appetite is much less than before
- My appetite is much greater than before
- I have no appetite at all
- I crave food all the time

Question 19: CONCENTRATION DIFFICULTY *
- I can concentrate as well as ever
- I can't concentrate as well as usual
- It is hard to keep my mind on anything for very long
- I find I can't concentrate on anything at all

Question 20: FATIGUE/TIREDNESS *
- I am no more tired or fatigued than usual
- I get more tired or fatigued more easily than usual
- I am too tired or fatigued to do a lot of the things I used to do
- I am too tired or fatigued to do most of the things I used to do

Question 21: LOSS OF INTEREST IN SEX *
- I have not noticed any change in my interest in sex
- I am less interested in sex than I used to be

- I am much less interested in sex than I used to be
- I have lost interest in sex completely

APPENDIX 12 – SELF-CONTROL SCALE

10-Item Self-Scoring Self-Control Scale

Adapted from
Tangney, J.P., Baumeister, R.F., Boone, A.L. (2004). High Self-Control Predicts Good Adjustment, Less Pathology, Better Grades, and Interpersonal Success. *Journal of Personality*, 271-324.

First, please read the following 10 statements and for each, check the box that best represents you.

	Not at all like me	A little like me	Some what like me	Mostly Like Me	Very much like me
I have a hard time breaking bad habits.	5	4	3	2	1
I get distracted easily.	5	4	3	2	1
I say inappropriate things.	5	4	3	2	1
I refuse things that are bad for me, even if they are fun.	1	2	3	4	5
I'm good at resisting temptation.	1	2	3	4	5
People would say that I have very strong self-discipline.	1	2	3	4	5
Pleasure and fun sometimes keep me from getting work done.	5	4	3	2	1
I do things that feel good in the moment but regret later on.	5	4	3	2	1
Sometimes I can't stop myself from doing something, even if I know it is wrong.	5	4	3	2	1
I often act without thinking through all the alternatives.	5	4	3	2	1

APPENDIX 13 – EMOTIONAL EATER QUESTIONNAIRE

Emotional Eater Questionnaire (EEQ) Garaulet			
1. *Do the weight scales have a great power over you? Can they change your mood?*			
☐ Never	☐ Sometimes	☐ Generally	☐ Always
2. *Do you crave specific foods?*			
☐ Never	☐ Sometimes	☐ Generally	☐ Always
3. *Is it difficult for you to stop eating sweet things, especially chocolate?*			
☐ Never	☐ Sometimes	☐ Generally	☐ Always
4. *Do you have problems controlling the amount of certain types of food you eat?*			
☐ Never	☐ Sometimes	☐ Generally	☐ Always
5. *Do you eat when you are stressed, angry or bored?*			
☐ Never	☐ Sometimes	☐ Generally	☐ Always
6. *Do you eat more of your favourite food and with less control when you are alone?*			
☐ Never	☐ Sometimes	☐ Generally	☐ Always
7. *Do you feel guilty when eat "forbidden" foods, like sweets or snacks?*			
☐ Never	☐ Sometimes	☐ Generally	☐ Always
8. *Do you feel less control over your diet when you are tired after work at night?*			
☐ Never	☐ Sometimes	☐ Generally	☐ Always
9. *When you overeat while on a diet, do you give up and start eating without control, particularly food that you think is fattening?*			
☐ Never	☐ Sometimes	☐ Generally	☐ Always
10. *How often do you feel that food controls you, rather than you controlling food?*			
☐ Never	☐ Sometimes	☐ Generally	☐ Always

APPENDIX 14 – EATING DISORDER EXAMINTATION QUESTIONNAIRE (ONLINE FORM)

Eating Disorder Examination Questionnaire

The following questions are concerned with the past four weeks (28 days) only. Please read each question carefully. Please answer all the questions. Thank you.

1.Before starting the questionnaire, please enter your participant code:*_____

Questions 1 to 12: Please indicate the appropriate number of days where applicable. Remember that the questions only refer to the past four weeks (28days) only.
On how many of the past 28 days .....

1.Have you been deliberately trying to limit the amount of food you eat toinfluence your shape or weight (whether or not you have succeeded)?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 – 27 days
- Everyday

2. Have you gone for long periods of time (8 waking hours or more) withouteating anything at all in order to influence your shape or weight?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 - 27 days
- Everyday

3. Have you tried to exclude from your diet any foods that you like in order to influence your shape or weight (whether or not you have succeeded)?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 - 27 days
- Everyday

4. Have you tried to follow definite rules regarding your eating (for example, acalorie limit) in order to influence your shape or weight (whether or not you have succeeded)?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 - 27 days
- Everyday

5. Have you had a definite desire to have an 'empty' stomach with the aim of influencing your shape or weight?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days

- 23 - 27 days
- Everyday

6. Have you had a definite desire to have a 'totally flat' stomach?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 - 27 days
- Everyday

7. Has thinking about food, eating or calories made it very difficult to concentration things you are interested in (for example, working, following a conversation, or reading) ?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 - 27 days
- Everyday

8. Has thinking about shape or weight made it very difficult to concentrate on things you are interested in (for example, working, following a conversation, or reading)?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 - 27 days
- Everyday

9. Have you had a definite fear of losing control over eating?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 - 27 days
- Everyday

10. Have you had a definite fear that you might gain weight?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 - 27 days
- Everyday

11. Have you felt fat?

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 - 27 days
- Everyday

12. Have you had a strong desire to lose weight?

No days
1 - 5 days
6 - 12 days
13 - 15 days
16 - 22 days
23 - 27 days

Everyday

Questions 13 -18: Please fill in the appropriate number in the spaces provided (such as completed above) Remember that the questions only refer to the past four weeks (28 days). Over the past four weeks (28 days) ...

13. How many times have you eaten what other people would regard as an unusually large amount of food (given the circumstances)?_____

14. On how many of these times did you have a sense of having lost control over your eating (at the time that you were eating)?_____

15. On how many DAYS have such episodes of overeating occurred (I.e., you have eaten an unusually large amount of food and have had a sense of loss of loss of control at the time)?_____

16. How many times have you made yourself sick (vomit) as a means of controlling your shape or weight?_____

17. How many times have you taken laxatives as a means of controlling your shape or weight?_____

18. How many times have you exercised in a "driven" or "compulsive" way as a means of controlling your weight, shape or amount of fat, or to burn off calories?_____

Questions 19 to 21: Please indicate the appropriate number where applicable. Please note that for these questions the term "binge eating" means eating what others would regard as an unusually large amount of food for the circumstances, accompanied by a sense of having lost control over eating.

19. Over the past 28 days, on how many days have you eaten in secret (i.e.furtively)? Do not count episodes of binge eating

- No days
- 1 - 5 days
- 6 - 12 days
- 13 - 15 days
- 16 - 22 days
- 23 - 27 days
- Everyday

20. On what proportion of the times that you have eaten have you felt guilty(felt that you've done wrong) because of its effect on you shape or weight? Do not count episodes of binge eating

- None of the times
- A few of the times
- Less than half
- Half of the times
- More than half
- Most of the time
- Every time

21. Over the past 28 days, how concerned have you been about other people seeing you eat? Do not count episodes of binge eating

- Not at all
- Slightly
- Moderately
- Markedly

Question 22 to 28: Please indicate the appropriate number where applicable. Remember that the questions only refer to the past four weeks (28 days).
Over the past 28 days...

22. Has your weight influenced how you think about (judge) yourself as a person?

- Not at all
- Slightly
- Moderately
- Markedly

23. Has your shape influenced how you think about (judge) yourself as a person?

- Not at all
- Slightly
- Moderately
- Markedly

24. How much would it have upset you if you had been asked to weigh yourselfonce a week (no more, or less, often) for the next four weeks?

- Not at all
- Slightly
- Moderately
- Markedly

25. How dissatisfied have you been with your weight?
Mark only one oval.

- Not at all
- Slightly
- Moderately
- Markedly

26. How dissatisfied have you been with your shape?

- Not at all
- Slightly
- Moderately
- Markedly

27. How uncomfortable have you felt seeing you body (for example, seeing your shape in the mirror, in a shop window reflection, while undressing or taking a bath or shower)?

- Not at all
- Slightly
- Moderatley
- Markedly

28. How uncomfortable have you felt about others seeing your shape or figure (for example, in communal changing rooms, when swimming, or wearing tight clothes)?

- Not at all
- Slightly
- Moderately
- Markedly

APPENDIX 15 – GENERAL PHYSICAL ACTIVITY QUESTIONNAIRE

GPAQ V2

Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person.
Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. *[Insert other examples if needed]*. In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.

		Response		Coding Column	
P 1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work]* for at least 10 minutes continuously? *INSERT EXAMPLES & USE SHOWCARD*	Yes No	1 2	☐	*If No, go to P3*
P 2a	In a typical week, on how many days do you do vigorous-intensity activities as part of your work?	Days a week		☐☐	
P 2b	How much time do you spend doing vigorous-intensity activities at work on a typical day?	In hours and minutes	hrs ☐☐ : mins ☐☐		
P 3	Does your work involve moderate-intensity activity, that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads]* for at least 10 minutes continuously? *INSERT EXAMPLES & USE SHOWCARD*	Yes No	1 2	☐	*If No, go to P5*
P 4a	In a typical week, on how many days do you do moderate-intensity activities as part of your work?	Days a week		☐☐	
P 4b	How much time do you spend doing moderate-intensity activities at work on a typical day?	In hours and minutes	hrs ☐☐ : mins ☐☐		
The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship. *[insert other examples if needed]*					
P 5	Do you walk or use a bicycle (*pedal cycle*) for at least 10 minutes continuously to get to and from places?	Yes No	1 2	☐	*If No, go to P7*
P 6a	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Days a week		☐☐	
P 6b	How much time do you spend walking or bicycling for travel on a typical day?	In hours and minutes	hrs ☐☐ : mins ☐☐		

		Response		Coding Column	
The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (*leisure*) *[insert relevant terms]*.					
P 7	Do you do any vigorous-intensity sports, fitness or recreational (*leisure*) activities that cause large increases in breathing or heart rate like [*running or football*,] for at least 10 minutes continuously? *INSERT EXAMPLES & USE SHOWCARD*	Yes No	1 2	☐	*If No, go to P9*
P 8a	In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational (*leisure*) activities?	Days a week		☐☐	
P 8b	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	In hours and minutes	hrs ☐☐ : mins ☐☐		
P 9	Do you do any moderate-intensity sports, fitness or recreational (*leisure*) activities that causes a small increase in breathing or heart rate such as brisk walking,[*cycling, swimming, volleyball*] for at least 10 minutes continuously? *INSERT EXAMPLES & USE SHOWCARD*	Yes No	1 2	☐	*If No, go to P 11*
P 10a	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational (*leisure*) activities?	Days a week		☐☐	
P 10b	How much time do you spend doing moderate-intensity sports, fitness or recreational (*leisure*) activities on a typical day?	In hours and minutes	hrs ☐☐ : mins ☐☐		
The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. INSERT EXAMPLES & USE SHOWCARD					
P 11	How much time do you usually spend sitting or reclining on a typical day?	In hours and minutes	hrs ☐☐ : mins ☐☐		

APPENDIX 16 - VAS

Date: _____ **Time:** _____ **Code:** _____

Instructions: Please make a mark on the line according to how you are feeling.

VISUAL ANALOGUE SCALE

1. **How hungry are you?**

Not al all hungry _____ Very hungry

2. **How full do you feel?**

Not at all full _____ Very full

3. **How strong is your desire to eat?**

Not at all strong _____ Very strong

APPENDIX 17 – BRIEF-A (ONLINE FORM)

Behavioural Rating Inventory of Executive Function (BRIEF-A)

Before starting the questionnaire, please enter your participant code:_____

1. I have angry outbursts *
- Never
- Sometimes
- Always

2. I make careless errors when completing tasks *
- Never
- Sometimes
- Always

3. I am disorganized *
- Never
- Sometimes
- Always

4. I have trouble concentrating on tasks (such as chores, reading or work) *
- Never
- Sometimes
- Always

5. I tap my fingers or bounce my legs *
- Never
- Sometimes
- Always

6. I need to be reminded to begin a task, even when I am willing *
- Never
- Sometimes
- Always

7. I have a messy closet *
- Never
- Sometimes
- Always

8. I have trouble changing from on activity or task to another *
- Never
- Sometimes
- Always

9. I get overwhelmed by large tasks *
- Never
- Sometimes
- Always

10. I forget my name *
- Never
- Sometimes
- Always

11. I have trouble with jobs or tasks that have more than one step *
- Never
- Sometimes
- Always

12. I overreact emotionally *
- Never
- Sometimes
- Always

13. I don't notice when I cause others to feel bad, or get mad until it is too late *
- Never

- Sometimes
- Always

14. I have trouble getting ready for the day *
- Never
- Sometimes
- Always

15. I have trouble prioritizing activities *
- Never
- Sometimes
- Always

16. I have trouble sitting still *
- Never
- Sometimes
- Always

17. I forget what I am doing in the middle of things *
- Never
- Sometimes
- Always

18. I don't check my work for mistakes *
- Never
- Sometimes
- Always

19. I have emotional outbursts for little reason *
- Never
- Sometimes
- Always

20. I lie around the house a lot *
- Never
- Sometimes
- Always

21. I start tasks (such as cooking projects) without the right materials *
- Never
- Sometimes
- Always

22. I have trouble accepting different ways to solve problems with work, friends, or tasks *
- Never
- Sometimes
- Always

23. I talk at the wrong time *
- Never
- Sometimes
- Always

24. I misjudge how difficult or easy tasks will be *
- Never
- Sometimes
- Always

25. I have problems getting started on my own *
- Never
- Sometimes
- Always

26. I have trouble staying on the same topic when talking *
- Never
- Sometimes
- Always

27. I get tired *
- Never
- Sometimes
- Always

28. I react more emotionally to situations than my friends *

- Never
- Sometimes
- Always

29. I have problems waiting my turn *
- Never
- Sometimes
- Always

30. People say that I am disorganized *
- Never
- Sometimes
- Always

31. I lose things (such as keys, money, wallet, homework, ect.) *
- Never
- Sometimes
- Always

32. I have trouble thinking of a different way to solve a problem when stuck *
- Never
- Sometimes
- Always

33. I overreact to small problems *
- Never
- Sometimes
- Always

34. I don't plan ahead for future activities *
- Never
- Sometimes
- Always

35. I have a short attention span *
- Never
- Sometimes
- Always

36. I make inappropriate sexual comments *
- Never
- Sometimes
- Always

37. When people seem upset with me I don't understand why *
- Never
- Sometimes
- Always

38. I have trouble counting to three *
- Never
- Sometimes
- Always

39. I have unrealistic goals *
- Never
- Sometimes
- Always

40. I leave the bathroom a mess *
- Never
- Sometimes
- Always

41. I make careless mistakes *
- Never
- Sometimes
- Always

42. I get emotionally upset easily *
- Never
- Sometimes
- Always

43. I make decisions that get me into trouble (legally, financially, socially) *
- Never
- Sometimes
- Always

44. I am bothered by having to deal with changes *
- Never
- Sometimes
- Always

45. I have difficulty getting excited about things *
- Never
- Sometimes
- Always

46. I forget instructions easily *
- Never
- Sometimes
- Always

47. I have good ideas but can not get them on paper *
- Never
- Sometimes
- Always

48. I make mistakes *
- Never
- Sometimes
- Always

49. I have trouble getting started on tasks *
- Never
- Sometimes
- Always

50. I say things without thinking *
- Never
- Sometimes
- Always

51. My anger is intense but ends quickly *
- Never
- Sometimes
- Always

52. I have trouble finishing tasks (such as chores, work) *
- Never
- Sometimes
- Always

53. I start things at the last minute (such as assignments, chores, tasks) *
- Never
- Sometimes
- Always

54. I have difficulty finishing a task on my own *
- Never
- Sometimes
- Always

55. People say that I am easily distracted *
- Never
- Sometimes
- Always

56. I have trouble remembering things even for a few minutes (such as directions, phone numbers) *
- Never
- Sometimes
- Always

57. People say that I am too emotional *
- Never

- Sometimes
- Always

58. I rush through things *
- Never
- Sometimes
- Always

59. I get annoyed *
- Never
- Sometimes
- Always

60. I leave my room or home a mess *
- Never
- Sometimes
- Always

61. I get disturbed by unexpected changes in my daily routine *
- Never
- Sometimes
- Always

62. I have trouble coming up with ideas for what to do with my free time *
- Never
- Sometimes
- Always

63. I don't plan ahead for tasks *
- Never
- Sometimes
- Always

64. People say that I don't think before acting *
- Never
- Sometimes
- Always

65. I have trouble finding things in my room, closet or desk *
- Never
- Sometimes
- Always

66. I have problems organizing activities *
- Never
- Sometimes
- Always

67. After having a problem, I don't get over it easily *
- Never
- Sometimes
- Always

68. I have trouble doing more than one thing at a time *
- Never
- Sometimes
- Always

69. My mood changes frequently *
- Never
- Sometimes
- Always

70. I don't think about consequences before doing something *
- Never
- Sometimes
- Always

71. I have trouble organizing work *
- Never
- Sometimes
- Always

72. I get upset quickly or easily over little things *

- Never
- Sometimes
- Always

73. I am impulsive *

- Never
- Sometimes
- Always

74. I don’t pick up after myself *

- Never
- Sometimes
- Always

75. I have problems completing my work *

- Never
- Sometimes
- Always

APPENDIX 18 – TURN-IT-IN REPORT

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