COPYRIGHT AND USE OF THIS THESIS

This thesis must be used in accordance with the provisions of the Copyright Act 1968.

Reproduction of material protected by copyright may be an infringement of copyright and copyright owners may be entitled to take legal action against persons who infringe their copyright.

Section 51 (2) of the Copyright Act permits an authorized officer of a university library or archives to provide a copy (by communication or otherwise) of an unpublished thesis kept in the library or archives, to a person who satisfies the authorized officer that he or she requires the reproduction for the purposes of research or study.

The Copyright Act grants the creator of a work a number of moral rights, specifically the right of attribution, the right against false attribution and the right of integrity.

You may infringe the author’s moral rights if you:

- fail to acknowledge the author of this thesis if you quote sections from the work
- attribute this thesis to another author
- subject this thesis to derogatory treatment which may prejudice the author’s reputation

For further information contact the University’s Director of Copyright Services

sydney.edu.au/copyright
The Role and Trainability of Executive Function in the Context of Healthy Eating

Vanessa Allom
School of Psychology
Faculty of Science
University of Sydney

A thesis submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy (PhD)
2014
Acknowledgements

I would like take this opportunity to thank my supervisors, Associate Professor Barbara Mullan and Dr Helen Paterson for their dedication, guidance, and support. Without their input, my work would be much diminished. Thank you also to my fellow students at the University of Sydney, especially Scott Griffiths and Daniel While, who made my office such an inspiring (and hilarious) place to spend time, and to the students and colleagues in the health psychology research lab who provided much insight and support. A special thank you to Kirby Sainsbury for her encouragement and support over the years, and for of course; printing and handing in my thesis. Also, to the wonderful Alexander Kammer, Tom Whittle, and Sean Pollock: thank you for being there for me throughout this entire journey, despite your claims that psychology is not a real science.

My work was supported by an Australian Postgraduate Award, and an Australian Research Council Linkage ‘top-up’ scheme. Additionally, this work, and the dissemination of this work at conferences, was assisted by smaller grants under the Postgraduate Research Support Scheme (PRSS), Postgraduate Research Grants (PRG), and Student Travel Allowance (STA) from the School of Psychology at the University of Sydney, for which I am very grateful.

Finally, I would like to thank Kirill Fayn. Without his passion for scientific enquiry and continued efforts to inspire and provoke thought, this thesis would not have been possible.
Abstract

Minimising intake of dietary fats and consuming appropriate amounts of fruit and vegetables reduce the risk of numerous negative health consequences. Self-regulation, and the processes underlying this capacity, namely executive functions, have been proposed to influence the adoption and maintenance of such healthy eating behaviours. In this thesis, a multi-method approach was taken to establish which facets of executive function were involved in healthy eating behaviour and whether these could be modified to improve eating behaviour. The results of a series of focus groups and a prospective study revealed that inhibitory control was specifically involved in fat intake, while updating ability was involved in fruit and vegetable consumption. A meta-analysis of current inhibitory control training studies revealed the need to assess change in eating behaviour using ecologically valid measures of eating behaviour, and to assess the mechanisms by which inhibitory control training influence eating behaviour. Results of an intervention based on these findings revealed that behaviour-specific stop-signal training led to a reduction in body mass index, which was mediated by changes in vulnerability to depletion. However, training did not result in a reduction in fat intake or an increase in inhibitory control capacity. The intervention was replicated to assess the reliability and longevity of the effects and to address methodological limitations. Results revealed that both behaviour-specific and general inhibitory control training improved inhibitory control capacity and decreased vulnerability to depletion; however, these improvements did not result in behaviour change, nor did they persist over time. While it appears that inhibitory control training alone may not be a suitable technique to change everyday eating behaviour, this technique may be efficacious for short-term improvement in self-regulatory outcomes, or when combined with other behaviour change techniques.
Publications relating to this thesis

The following publications are related to this thesis and are included in the Appendices.


# Table of Contents

## Chapter 1 – Introduction

Aims and scope ......................................................................................................................... 2

Overview of thesis ..................................................................................................................... 2

Stage 1: Theories of health behaviour: where does self-regulation fit in? ....................... 5

Stage 2: Exploring implicit theories of self-regulation and eating behaviour ............... 5

Stage 3: Prediction of eating behaviour using executive function constructs ............... 5

Stage 4: Determining the efficacy of current executive function training interventions ... 6

Stage 5: Inhibitory control training and eating behaviour: Addressing remaining questions ................................................................................................................................. 6

## Chapter 2 – Predicting Eating Behaviour: Theoretical models and self-regulation

Obesity ........................................................................................................................................... 8

Eating behaviour and health risk .............................................................................................. 9

Healthy eating guidelines and adherence ............................................................................... 11

Predicting and explaining unhealthy eating behaviour ..................................................... 12

  Closing the intention-behaviour gap: adding variables to the theory of planned behaviour ......................................................................................................................... 14

Temporal self-regulation theory .............................................................................................. 17

Dual-systems explanations .................................................................................................... 21

Conclusions ................................................................................................................................. 24

## Chapter 3 – Processes underlying self-regulation: Executive functions

Shifting ......................................................................................................................................... 28
Chapter 4 – How do healthy eaters describe their ability to self-regulate? A qualitative analysis

Eating behaviour of young adults

Examining the eating behaviour of healthy individuals

Aims

Methods

Participants

Procedure

Measures

Coding

Results

Healthy eating enablers and barriers

Coping with environment barriers

Nature of self-regulation

Habit

Discussion
Chapter 5 - Prediction of eating behaviour using executive function constructs ......... 76

Executive function and unhealthy eating .............................................. 76
Executive function and healthy eating ................................................. 78
Avoiding consumption of unhealthy foods versus initiating consumption of healthy foods ................................................................. 79
Eating style ......................................................................................... 80
Aims and hypotheses .......................................................................... 80

Method .............................................................................................. 81
Participants ....................................................................................... 81
Materials and measures ....................................................................... 81
Procedure .......................................................................................... 85
Data analysis ...................................................................................... 85

Results .............................................................................................. 86
Outliers .............................................................................................. 86
BMI .................................................................................................... 86
Correlations ....................................................................................... 86
Chapter 6 - Determining the efficacy of current executive function training interventions

Updating training

Inhibitory control training

Potential moderators of training effect

Present analysis

Method

Inclusion and exclusion criteria

Information extracted and meta-analytic strategy

Moderator coding

Risk of bias

Results

Characteristics of included studies
Chapter 7 – Inhibitory control training and eating behaviour: Addressing remaining questions

Overall training effect ................................................................. 117
Moderator analyses ...................................................................... 119
Discussion .................................................................................. 124
Type of task .................................................................................. 125
Length of training ......................................................................... 127
Behaviour ...................................................................................... 127
Stability of effect .......................................................................... 128
Strengths and limitations .............................................................. 128
Conclusions ................................................................................ 130

Index

Chapter 7 – Inhibitory control training and eating behaviour: Addressing remaining questions ............................................ 131

Improvement in inhibitory control ............................................ 131
Decrease in vulnerability to depletion ....................................... 133
Addressing additional concerns .................................................. 134
Aims and hypotheses ................................................................. 135
Methods ...................................................................................... 136
Participants .................................................................................. 136
Materials and measures ............................................................. 137
Procedure .................................................................................... 139
Data analysis ................................................................................ 140
Results ......................................................................................... 141
Randomisation check ................................................................. 141
Chapter 8 – Inhibitory control training and eating behaviour: Reliability and longevity of effects, and acceptability and feasibility of intervention

Reliability and longevity of effects

Acceptability and feasibility of the intervention

Aims & hypotheses

Method

Participants

Materials and measures

Procedure

Data analysis

Results

Randomisation check

Attrition

Depletion

Training effects
Acceptability and feasibility of the intervention .................................................. 167

Discussion ...................................................................................................................... 171

Effect of training on self-regulatory outcomes and eating behaviour ....................... 171

Longevity of effects ...................................................................................................... 174

Acceptability and feasibility ......................................................................................... 174

Implications .................................................................................................................... 175

Strengths and limitations ............................................................................................... 176

Conclusions ..................................................................................................................... 177

Chapter 9: General Discussion ..................................................................................... 178

Summary of research findings ....................................................................................... 178

Stage 1: Theories of health behaviour: where does self-regulation fit in? ............... 180

Stage 2: Exploring implicit theories of self-regulation and eating behaviour ........... 181

Stage 3: Prediction of eating behaviour using executive function constructs .......... 182

Stage 4: Determining the efficacy of current executive function training interventions .......................................................................................................................... 182

Stage 5: Inhibitory control training and eating behaviour change: Addressing remaining questions ............................................................................................................ 183

Implications and directions for future work ............................................................... 184

Strengths and limitations of this research ................................................................... 187

Conclusions ..................................................................................................................... 188

References .................................................................................................................... 189

Appendices ..................................................................................................................... 229
List of Figures

Figure 1.1. Outline of the research conducted in this thesis………………………………….4

Figure 2.1. The theory of planned behaviour……………………………………………..……13

Figure 2.2. Temporal self-regulation theory………………………………………………….19

Figure 2.3. Reflective-impulsive model of goal-directed behaviour……………………….22

Figure 3.1. Wisconsin card sorting task…………………………………………………………….29

Figure 3.2. A simplified trail making task, part B………………………………………………..30

Figure 3.3. The Stroop interference task………………………………………………………….34

Figure 3.4. The stop-signal task and the go/no-go task………………………………………...35

Figure 3.5. N-back with examples of 1-, 2- and 3-back……………………………………..41

Figure 3.6. Operation span task……………………………………………………………………42

Figure 6.1. Flow diagram for the search and inclusion criteria for studies in the meta-analysis………………………………………………………………………………………………111

Figure 6.2. Forest plot of effect sizes for inhibitory control training and health outcomes...118

Figure 7.1. Study flowchart indicating measures at each time point………………………….140

Figure 7.2. Amount of depletion (difference in Stroop interference scores pre- to post-depletion task) experienced pre- and post-intervention for each condition……………….144
Figure 7.3. Body mass index pre- and post- intervention for each condition……………….145

Figure 7.4. Simple mediation model depicting the indirect effect of type of training on change in Body Mass Index through change in vulnerability to depletion……………….146

Figure 8.1. Study flowchart indicating measures at each time point…………………….159

Figure 8.2. Inhibitory control performance (Stroop interference scores in ms) pre-intervention, post-intervention and at follow-up for each condition……………………….164

Figure 8.3. Amount of depletion (difference in Stroop interference scores pre- to post-depletion task in ms) experienced pre-intervention, post-intervention and at follow-up for each condition………………………………………………………………………….166

Figure 9.1. Outline of research conducted in this thesis………………………………….179
List of Tables

Table 3.1 Summary of Studies Examining the Relationship between Shifting and Eating Behaviour

Table 3.2 Summary of Studies Examining the Relationship between Inhibitory Control and Eating Behaviour

Table 3.3 Summary of Studies Examining the Relationship between Updating Ability and Eating Behaviour

Table 4.1 Themes by Focus Group Session

Table 4.2 Representative Quotes for Theme 1: Healthy Eating Enablers and Barriers, with Focus Group Indicated

Table 4.3 Representative Quotes for Theme 2: Coping with Environmental Barriers, with Focus Group Indicated

Table 4.4 Representative Quotes for Theme 3: Nature of Self-Regulation, with Focus Group Indicated

Table 4.5 Representative Quotes for Theme 4: Habit, with Focus Group Indicated

Table 5.1 Means, Standard Deviations, and Pearson’s Correlations of BMI, Eating Styles, Executive Function and Saturated Fat Intake and Fruit and Vegetable Consumption

Table 5.2 Hierarchical Regression Analysis for Prediction of Saturated Fat Intake
Table 5.3 Hierarchical Regression Analysis for Prediction of Fruit and Vegetable Consumption

Table 6.1 Effect Sizes and Characteristics of Studies Included In the Meta-Analysis

Table 6.2 Moderator Analysis of the Size of the Effect of Inhibitory Control Training on Health Behaviour

Table 7.1 Means and Standard Deviations of All Outcome Variables for Each Condition Pre- and Post- Intervention

Table 8.1 Means and Standard Deviations of All Outcome Variables for Each Condition at Pre-Intervention, Post-Intervention, and Follow-Up

Table 8.2 Sample Means and Proportion Agreed for Online SST Training Feasibility and Acceptability Items

Table 8.3 Representative Quotes for Acceptability and Feasibility of the Intervention
Chapter 1 – Introduction

Overweight and obesity are major health problems worldwide, with 61% of the Australian population (Australian Bureau of Statistics, 2009) and 69% of the population of the United States of America (Allender, Cowburn, & Foster, 2006) being either overweight or obese. Further, it appears that the prevalence of overweight and obesity is increasing (Colagiuri et al., 2010; Flegal, Carroll, Ogden, & Curtin, 2010). There are a variety of health risks associated with obesity including cardiovascular diseases, hypertension, cancer and diabetes (Visscher & Seidell, 2001). Additionally, obesity has numerous economic and social impacts with the total financial cost of obesity in Australia, including health system costs, loss of productivity costs, and carers' costs, estimated at $58 billion in 2008 (Access Economics, 2008; Colagiuri et al., 2010). While there are numerous factors that contribute to being overweight or obese, an increase in the consumption of energy-dense foods without a corresponding increase in energy expenditure appears to be the fundamental cause (World Health Organisation, 2006). Therefore, in order to begin to address the obesity problem, an understanding of the factors associated with eating behaviour, and an examination of whether such factors can be modified, is crucial.

Explaining human behaviour, particularly health behaviour, is not simple and modifying such behaviours has proven difficult (Webb & Sheeran, 2006). Often behaviours that are immediately gratifying are favoured at the cost of long-term health benefits. For example, it is not uncommon for individuals to choose an unhealthy food that is convenient and palatable over a healthy option that is less immediately rewarding, but has long-term health benefits. Further, while the benefits of performing health enhancing behaviours are generally understood, and most people form goals to carry out these behaviours, many people have difficulty translating these goals into action (McEachan, Conner, Taylor, & Lawton, 2011). Yet, some individuals do manage to carry out their health-related goals. Research has
suggested that our ability to self-regulate is crucial to the translation of goals into behaviour (Hagger, 2010). Indeed, several higher-order neurocognitive processes, such as inhibitory control, planning and flexibility of thought, have been linked to health behaviours including healthy eating (Allom & Mullan, 2012; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010), binge drinking (Houben & Wiers, 2009; Mullan, Wong, Allom, & Pack, 2011), and sun protection (Allom, Mullan, & Sebastian, 2013). However, several questions pertaining to the precise nature of such processes, and their relationship to health behaviours including healthy eating, remain unanswered. Given the increasing need to reduce the prevalence of overweight and obesity, establishing the nature of potentially influential processes, and the efficacy of healthy eating strategies derived from such processes, is greatly desired.

**Aims and scope**

The purpose of this thesis is to examine the role of self-regulation in the context of healthy eating. Of particular interest is the manner in which higher-order neurocognitive processes; or executive functions, enable the regulation of eating behaviour. Using a multi-methods approach, the specific aim is to establish which elements of executive function are related to eating behaviour and to determine whether such elements can be modified to improve eating behaviour.

**Overview of thesis**

Initially, an overview of eating behaviour and theories used to predict and explain eating behaviour is provided. A specific emphasis is placed on the role of self-regulation in these theories. Secondly, the underlying processes that contribute to successful self-regulation, namely executive functions, are described. In the first study, a qualitative exploration of the factors that successful self-regulators see as influential in the maintenance of healthy eating behaviour is reported. Following this, a predictive study that quantitatively establishes the key elements of executive function associated with particular eating
behaviours is presented. Next, the efficacy of interventions designed to modify health
behaviour through executive function training is assessed through a meta-analysis. An
intervention developed from the findings presented is then reported and subsequently
replicated. Finally, an evaluation of the intervention is described. The research is divided into
five sections as described in Figure 1. The rationale for the design of each stage is presented
below.
Figure 1.1. Outline of the research conducted in this thesis.
Stage 1: Theories of health behaviour: where does self-regulation fit in?

The purpose of this stage was to provide an overview of research linking obesity and unhealthy eating to negative health consequences, and to review the psychological theories that are typically used to predict and modify eating behaviour. The role of self-regulation within these theories was discussed. Subsequently, the underlying processes thought to be responsible for successful self-regulation were described, and previous applications of such processes to the prediction of eating behaviour, were synthesised.

Stage 2: Exploring implicit theories of self-regulation and eating behaviour

Research has established the importance of self-regulation in maintaining a healthy diet and weight. However, limited research has explored the manner in which individuals conceptualise their ability to self-regulate, and whether individuals perceive self-regulation to be of importance. Additionally, previous qualitative research examining the factors that are associated with unhealthy eating has primarily explored the cognitions and experiences of overweight or obese individuals (Bidgood & Buckroyd, 2005; Garip & Yardley, 2011). In contrast, limited research has considered individuals who are able to successfully regulate their eating behaviour. Chapter 4 reports on a series of focus groups in which the perceptions and experiences of successful healthy eaters were explored in order to determine the factors and self-regulatory processes that these individuals see as influential in the regulation of eating behaviour.

Stage 3: Prediction of eating behaviour using executive function constructs

The next step was to employ a predictive methodology in order to apply the findings from Chapter 4 in a quantitative context; that is, the elements of self-regulation that were indicated as influential in the regulation of eating behaviour were applied to the prediction of eating behaviour. A predictive approach was taken to determine which elements of executive function should be targeted in an intervention aimed at reducing harmful eating behaviour.
Finally, it was deemed important to establish the predictive utility of executive function over and above other variables that have been previously established as influential in the prediction of eating behaviour. As such, Chapter 5 reports on a predictive study that examines the relationship between two categories of executive function and eating behaviour while controlling for variables that have previously been established as influential in the regulation of eating behaviour (e.g., dietary restraint).

Stage 4: Determining the efficacy of current executive function training interventions

After identifying which elements of executive function were associated with eating behaviour, the next step was to determine whether training of a particular element of executive function (inhibitory control) could improve the regulation of harmful behaviours. In order to achieve this, a meta-analysis of inhibitory control training interventions and behaviour regulation was conducted. The scope of the analysis extended beyond eating behaviour as the number of studies that tested the relationship between inhibitory control training and eating behaviour was limited. Additionally, it was considered important to assess all available evidence on how different training methodologies influenced the effect of training on behavioural outcomes. Chapter 6 reports the results of this meta-analysis.

Stage 5: Inhibitory control training and eating behaviour: Addressing remaining questions

Results of the meta-analysis revealed that the majority of studies utilising inhibitory control training to improve behaviour regulation did not assess change in eating behaviour. In terms of eating behaviour interventions, few included an assessment of the potential underlying mechanisms responsible for change. In addition, ecologically valid measures of eating behaviour were seldom used. Consequently, Chapter 7 reports on an evidenced-based intervention to improve eating behaviour, and assess the underlying mechanisms, which was implemented and assessed in a randomised controlled trial design. The second part of this stage was a replication of the inhibitory control and eating behaviour intervention to firstly
determine the reliability and longevity of the observed effects, and to secondly address the
limitations of the original intervention. Finally, the acceptability and feasibility of the
intervention was assessed.
Chapter 2 – Predicting Eating Behaviour: Theoretical models and self-regulation

Obesity

The consumption of unhealthy foods, together with an inactive lifestyle, is resulting in increasing numbers of people who are overweight and obese, not only in high-income countries but also in developing middle-income countries (Dinsa, Goryakin, Fumagalli, & Suhrcke, 2012; Monteiro, Moura, Conde, & Popkin, 2004). The past 30 years has seen an increase in overweight and obesity globally: the percentage of adults who were overweight or obese grew from 23% in 1980 to 34% in 2008 (Keats & Wiggins, 2014). The number of people who were overweight or obese in high-income countries increased 1.7 times over this period (Stevens et al., 2012). In Australia, data from the Australian Diabetes, Obesity, and Lifestyle study indicated that approximately one-fifth of normal-weight or overweight Australians progressed to a higher weight category from 2000 to 2005 (Barr et al., 2006). Between 2000 and 2025, it is estimated that the adult prevalence of normal-weight will decrease from 40.6 to 28.1% and the prevalence of obesity will increase from 20.5 to 33.9%. If these estimations are correct, normal-weight adults will constitute less than a third of the population by 2025, and the obesity prevalence will have increased by 65% (Walls et al., 2012).

Being overweight or obese increases the risk of negative health consequences and is associated with a substantial reduction in life expectancy. The prevalence of overweight and obesity is commonly assessed using a height/weight formula, known as body mass index (BMI). World Health Organisation criteria define overweight as a BMI of at least 25 kilograms/metre\(^2\) and obesity as a BMI of at least 30 kilograms/metre\(^2\) (World Health Organisation, 2006). These markers provide common benchmarks for assessment, but the risk of disease in most populations increases progressively from BMI levels of 20–22.
kilograms/metre$^2$ (World Health Organisation, 2002). Data from the United States of America suggest that a severe level of obesity (BMI > 45 kg/m$^2$) during early adulthood (aged 20–30 years) may reduce male life expectancy by up to 13 years and female life expectancy by up to eight years (Fontaine, Redden, Wang, Westfall, & Allison, 2003).

This reduction in life expectancy is due to the numerous non-communicable diseases with which overweight and obesity is associated, such as cardiovascular heart disease (Hubert, Feinleib, McNamara, & Castelli, 1983), type 2 diabetes (Kahn, Hull, & Utzschneider, 2006), gall bladder disease, ischaemic stroke (Strazzullo et al., 2010), and some types of cancers (Harvey et al., 2011; World Health Organisation, 2000). Specifically, obesity has been linked to increased blood pressure (Hajjar & Kotchen, 2003), cholesterol (Miettinen & Gylling, 2000), and build-up of fat deposits on artery walls (De Michele et al., 2002), which all contribute to cardiovascular disease. Australian data indicate that in 2007-08 3.4 million Australians or 17% of the population had a cardiovascular condition (Australian Institute of Health and Welfare, 2012). Cardiovascular disease kills more people than any other disease (accounting for 34% of all deaths in 2008) and it accounts for the largest share of health expenditure (World Health Organisation, 2002). However, much of the death, disability and illness, caused by non-communicable diseases that result from obesity, is preventable.

**Eating behaviour and health risk**

The majority of the burden of obesity related-disease is associated with two dietary risk factors: high intake of saturated fat and inadequate consumption of fruit and vegetables (Mente, de Koning, Shannon, & Anand, 2009; World Health Organisation, 2004). Research has consistently correlated increase in dietary fat consumption to the increased incidence of obesity (Bray & Popkin, 1998; Paeratakul, Popkin, Keyou, Adair, & Stevens, 1998), and further to the increase in mortality by cardiovascular disease (Brunner et al., 2008; Siri-
Tarino, Sun, Hu, & Krauss, 2010), and type 2 diabetes (Marshall & Bessesen, 2002; Misra, Singhal, & Khurana, 2010). Specifically, a recent meta-analysis of studies examining the relationship between saturated fat intake and mortality revealed that a higher intake of saturated fat from meat was significantly associated with increased risk of cardiovascular disease mortality (O’Sullivan, Hafekost, Mitrou, & Lawrence, 2013). Additionally, research has indicated that a diet high in saturated fat is associated with increased risk of breast cancer mortality (Makarem, Chandran, Bandera, & Parekh, 2013). Correspondingly, a review of results from 28 clinical trials, which studied the effects of reducing the amount of energy from dietary fat, showed that a reduction of 10% in the proportion of energy from fat was associated with a significant reduction in weight (Bray & Popkin, 1998). Therefore, it appears that the consumption of dietary fats, and particularly saturated fat, is strongly related to obesity and mortality from related illnesses.

Similarly, inadequate fruit and vegetable consumption has been linked to poor health outcomes. The World Health Organisation has estimated that inadequate fruit and vegetable intake is the cause of 31% of ischaemic heart disease, 11% of stroke (World Health Organisation, 2002), and 5–12% of cancers (International Agency for Research on Cancer, 2003). It has further been estimated that 85% of the global burden of disease, attributable to low fruit and vegetable intake, is related to cardiovascular diseases (World Health Organisation, 2002), suggesting that the consumption of fruit and vegetables is protective against such non-communicable diseases (Bazzano, Serdula, & Liu, 2003). Specifically, a recent longitudinal examination of the benefits of fruit and vegetable consumption indicated that for every 200 grams/day higher intake of fruits and vegetables combined, the risk of death was 3%–6% lower (Leenders et al., 2013). Further, it appears that consumption of fruit and vegetables is likely to be an important factor in weight regulation because, in comparison to other foods, most fruits and vegetables are energy dilute and have high fibre content.
This has led the World Health Organisation to recommend increased consumption of fruit and vegetables as a means of reducing obesity at a population level (FAO/WHO, 2003).

**Healthy eating guidelines and adherence**

Due to the link between high saturated fat intake, inadequate fruit and vegetable consumption and chronic diseases, governments around the world have developed guidelines which outline recommended consumption levels for these food groups (National Health and Medical Research Council, 2003; World Health Organisation, 2000). In Australia, the national guidelines suggest that an individual’s saturated fat intake should not exceed 10% of their total energy intake; that is, no more than 24 grams per day; and that individuals should consume two servings of fruit (150 grams each) and five servings (75 grams each) of vegetables each day (National Health and Medical Research Council and New Zealand Ministry of Health, 2006). While there may be slight differences (e.g., in the United Kingdom, five servings of fruit and vegetables; 80 grams each, are recommended), similar guidelines exist for the United Kingdom (Food Standards Agency, 2007) and the United States of America (US Department of Agriculture & US Department of Health and Human Services, 2010).

Many individuals experience difficulty adhering to these guidelines (Australian Institute of Health and Welfare, 2012; McLennan & Podger, 1998). Data from the 1995 National Nutrition Survey indicated that Australian adults’ total fat (including saturated, monounsaturated and polyunsaturated) intake accounted for about 33% of the total energy intake. Specifically, saturated fat constituted 13% of the total energy of Australian adults (Australian Bureau of Statistics, 1997). This is equivalent to an average daily consumption of 31 grams of saturated fat. In the United Kingdom, most individuals eat 20% more than the recommended amount of saturated fat (National Health Services, 2013), whilst in the United
States of America 12-15% of energy comes from saturated fat (German & Dillard, 2004).

Finally, rates of consumption of saturated fat and total fat have increased greatly amongst young adults. A study examining food and nutrient intake in undergraduate students, which compared rates of consumption of a variety of foods in 2009 with rates in 1999, revealed that intake of meats, milk and milk products, and manufactured food had increased (all of which contain high levels of fat), suggesting that saturated fat intake has increased greatly in this population (Jang et al., 2011).

Rates of fruit and vegetable consumption are similarly poor. Australian data from the 2007–2008 National Health Survey revealed that only 6.1% of all Australians aged 15 years and above met dietary guidelines for vegetable consumption, while 51.3% met the dietary guidelines for fruit consumption (Australian Bureau of Statistics, 2009). These results reflect findings from the United States of America, where 80% of all adults consumed fewer than five servings of fruit and vegetables each day in 2005 (Blanck, Gillespie, Kimmons, Seymour, & Serdula, 2008). Finally, young adults appear to be particularly poor at adhering to guidelines. An age-stratified analysis of mean fruit and vegetable consumption rates across 14 global regions found that fruit and vegetable consumption was lowest or second lowest amongst 15–29 year-olds in all regions (World Health Organisation, 2004).

**Predicting and explaining unhealthy eating behaviour**

The above evidence suggests that individuals experience great difficulty adhering to the recommended intake of fruit and vegetables, and saturated fat. Numerous theoretical models have been designed in an attempt to predict and explain why individuals may or may not engage in health risk behaviours such as over-consumption of saturated fat and health enhancing behaviours such as fruit and vegetable consumption. Several of these models suggest that reflective precursors, such as intention to perform a health behaviour, are essential to the execution of that behaviour. For example, in the theory of planned behaviour
(TPB; Ajzen, 1991), it is suggested that intentions are the immediate precursor to the performance of any behaviour, such that the stronger the intention to perform a behaviour, the more likely that it will be performed (Ajzen, 1991). The TPB also describes the determinants of intention formation: attitudes, subjective norm, and perceived behaviour control. According to the theory, individuals will intend to perform a behaviour to the extent that they believe the likely outcomes to be favourable (attitude), that they perceive social pressure from people who are important to them (subjective norm), and that they feel capable of performing the behaviour without difficulty (perceived behavioural control; Fishbein & Ajzen, 2010). In addition to its influence on intention, perceived behavioural control is also thought to have a direct influence on behaviour (Fishbein & Ajzen, 2010). The TPB model is displayed in Figure 2.1.

Figure 2.1. The theory of planned behaviour

The TPB has been empirically tested in many domains including the dietary behaviours of saturated fat intake (de Bruijn, Kroese, Oenema, & Brug, 2008) and fruit and
vegetable consumption (de Bruijn et al., 2007). While attitudes, subjective norm and perceived behavioural control are consistently shown to account for substantial variance in intention, most research reveals that intention is not as effective at predicting behaviour (Godin & Kok, 1996; Wenting & Guangrong, 2008). For example, Australian studies which employed the TPB to the prediction of saturated fat intake found that intention only accounted for approximately 25% of the variance in self-reported saturated fat intake (Mullan, Allom, Brogan, Kothe, & Todd, 2014; Mullan & Xavier, 2013). Additionally, research has shown that intention only accounts for between 9 - 17% of variance in self-reported fruit and vegetable consumption (Allom & Mullan, 2012; Kothe, Mullan, & Butow, 2012; Mullan et al., 2014).

This reflects a general trend that is present in the majority of applications of the TPB to the prediction of behaviour. In a meta-analysis including 237 independent studies of the predictive potential of the TPB for a variety of health-related behaviours, the TPB was found to explain 44% of the variance in intention but only 19% of the variance in behaviour (McEachan et al., 2011). Further, Webb and Sheeran (2006) conducted a meta-analysis of 47 experimental studies examining the causal influence of intention change on behaviour change and found that intervention-induced medium-to-large changes in intention ($d = 0.66$) only produced small-to-medium changes in behaviour ($d = 0.36$). These findings indicate that the relationship between intention and behaviour is not uniform nor consistent. Rather, a theoretical ‘gap’ exists between intention and behaviour, which may be moderated by factors not captured in the TPB.

**Closing the intention-behaviour gap: adding variables to the theory of planned behaviour**

In order to improve the predictive validity of the TPB and close the intention-behaviour gap, several researchers have included additional variables, which moderate the relationship between intention and behaviour. For example, research has shown that the
inclusion of anticipated affect (Conner, Godin, Sheeran, & Germain, 2013) and moral norms (Juraskova et al., 2012) both influence whether intentions are carried out. However, while these constructs have contributed to the prediction of behaviour in some studies, the variance explained has been small (Rivis, Sheeran, & Armitage, 2009) and inconsistent (Sandberg & Conner, 2008). Another construct that has been the focus of considerable study, in terms of improving the predictive utility of the TPB, is past behaviour. A number of studies have shown past behaviour to be the strongest predictor of future behaviour, often exceeding the predictive power of intention and other constructs described in the TPB (Norman & Smith, 1995; Ouellette & Wood, 1998; Verplanken & Orbell, 2003). However, despite the importance of past behaviour in predicting future behaviour, as Ajzen himself has long argued (Ajzen, 2002); past behaviour is not a useful variable to target as it cannot be modified in order to change behaviour. Thus, where the desire is to identify variables that are amenable to change, rather than just to the prediction of behaviour, past behaviour is not a useful construct.

A construct that may be of more use, and that has been consistently implicated in the successful execution of health behaviour goals, is self-regulation (Hagger, 2010; Hofmann et al., 2012). Self-regulation has been defined as the wilful regulation of cognition and responses in order to achieve long-term goals (Baumeister, Schmeichel, & Vohs, 2007). Self-regulation encompasses a variety of abilities and strategies that can be employed to regulate behaviour such as planning and self-monitoring. For example, a specific self-regulatory strategy, which has been employed numerous times to improve the execution of health behaviours, is referred to as implementation intentions. Implementation intentions involve specifying the precise behaviour that is required to achieve a health goal and the situational context in which it will be enacted (Gollwitzer, 1999). A meta-analysis of the effect of forming implementation intentions on the performance of health behaviours indicated a
medium-to-large effect ($d = 0.65$) of this strategy on goal attainment (Gollwitzer & Sheeran, 2006). Additionally, implementation intentions have been shown to moderate the relationship between intention and behaviour such that when intention strength was strong, individuals benefited from forming implementation intentions (Sheeran, Webb, & Gollwitzer, 2005). Recently, these results have been qualified by the finding that sufficient planning ability is required to successfully form and execute implementation intentions (Allan, Sniehotta, & Johnston, 2013).

Research has demonstrated that self-regulation is involved in both saturated fat intake (Friese, Hofmann, & Wanke, 2008; Hofmann, Friese, & Roefs, 2009; Mullan et al., 2014) and fruit and vegetable consumption (Allom & Mullan, 2012). Specifically, one study demonstrated that individuals with poorer self-regulation tended to consume more high-fat foods (Hall, 2012). Further, the effect of self-regulation on unhealthy food consumption was present when controlling for variables that have previously been shown to influence eating behaviour such as demographic characteristics, BMI, and general cognitive function. Additionally, Allan, Johnston, and Campbell (2010) demonstrated that amongst individuals who intended to eat healthily, poorer self-regulation was related to increased chocolate consumption in a pseudo taste test. Finally, self-regulation has also been implicated in the translation of fruit and vegetable consumption intentions into actual behaviour. Allom and Mullan (2012) demonstrated that amongst those who considered themselves to be healthy eaters, superior self-regulatory ability was associated with greater fruit and vegetable consumption and also moderated the relationship between intention and behaviour such that those with a higher self-regulatory ability were more likely to carry out their intentions. These results appear to indicate that the ability to regulate behaviour in line with long-term goals increases the likelihood of translating intention into behaviour.
While self-regulation appears to be a useful construct that aids in closing the intention-behaviour gap, the approach of simply adding variables to the TPB, in order to improve the predictive utility of this model, has been questioned. Specifically, in a recent critique of the validity and utility of the TPB, Sniehotta, Presseau, and Araújo-Soares (2014) suggest that ‘extended-TPB’ models undermine the contribution of constructs such as self-regulation to the prediction of behaviour. Further, continually employing a model that does not account for sufficient variance in behaviour may thwart the development of novel models, which potentially offer more accurate explanations of health behaviour. Sniehotta et al. (2014) suggest that models which do not assume reflective processes to be the primary precursors of behaviour, and those which are designed to take into account the nature of the target behaviour, may offer a more complete picture of how health behaviours are executed.

**Temporal self-regulation theory**

As suggested above, it may be important to consider the nature of the target behaviour when attempting to predict and modify health behaviours. Specifically, it has been suggested that the execution of health behaviours depends on the temporal dimensions of the particular health behaviour in question (Hall & Fong, 2007). For example, many health risk behaviours such as saturated fat intake result in considerable long-term costs but also have immediate benefits and relatively few short-term costs. That is, consuming foods high in saturated fat has the long-term costs of obesity, and related chronic illnesses, but also provides immediate gratification for many who find these foods to be palatable and convenient. In contrast, many health enhancing behaviours such as fruit and vegetable consumption are associated with long-term benefits, such as lower risk of chronic illnesses, but appear to have immediate costs (e.g., more expensive and greater time spent in preparation), making the performance of the health enhancing behaviours less desirable than the performance of the health risk behaviours.
Research has consistently shown that individual differences in future orientation; the ability to focus on the future consequences of present actions, relates to the performance of health behaviours. Piko and Brassai (2009) found that, in adolescents, lower levels of future orientation were associated with poor dietary control. Further, Luszczynska, Gibbons, Piko, and Tekozel (2004) found that future time perspective was significantly related to nutrition across four samples in different countries. Specifically, Gellert, Ziegelmann, Lippke, and Schwarzer (2012) demonstrated that individuals who were future orientated were more likely to enact their fruit and vegetable consumption intentions regardless of forming plans to do so. Conversely, those who were limited in their future orientation relied on plans to carry out their fruit and vegetable consumption intentions. It appears that taking into account the temporal dimensions of health behaviours, and the ability to coordinate between short-term and long-term costs and benefits, enables better prediction of health behaviour.

Hall and Fong (2007) highlight the importance of the temporal dimensions of health behaviours, and the ability to regulate behaviour in line with long-term goals, in their model of health behaviour. Temporal self-regulation theory (TST) takes into account motivational factors, such as intention, but also offers a way to close the intention-behaviour gap. It is suggested that two additional factors influence the translation of intention into behaviour: self-regulation (as described in the previous section) and behavioural prepotency (Hall & Fong, 2007). Behavioural prepotency can be understood as the likelihood of performance of a given behaviour as a function of habit or past behaviour, and internal and external cues to action. Importantly, it is suggested that the role of these additional factors differs according to the temporal contingencies associated with the particular health behaviour. For example, for repetitive behaviours with unfavourable temporal contingencies (i.e., immediate costs and long-term benefits), behaviour will be a function of intention, self-regulation and behavioural prepotency and the latter two factors will moderate the relationship between intention and
behaviour. Alternatively, for repetitive behaviours with immediate benefits and long-term costs, behaviour will primarily be a function of self-regulation and behavioural prepotency, and secondly as a function of intention. A pictorial representation of TST can be seen in Figure 2.

*Figure 2.2. Temporal self-regulation theory adapted from Hall and Fong (2007). Arrows between self-regulation and behavioural prepotency to the intention–behaviour arrow indicate moderation.*

Previous research examining the validity of the TST model has provided support for the role of various elements in the model. For example, de Bruijn et al. (2008) found that behavioural prepotency, as measured by habit strength, accounted for a significant proportion of variance in saturated fat intake over and above intention and moderated the relationship between intention and behaviour. Additionally, Hall, Fong, Epp, and Elias (2008) demonstrated that self-regulation directly predicted fruit and vegetable consumption and
moderated the relationship between intention and behaviour. However, research employing the full TST model to the prediction of eating behaviour has produced mixed results. For example, Collins and Mullan (2011) attempted to predict snacking behaviour and fruit and vegetable consumption using the TST, categorising snacking behaviour as a behaviour with favourable temporal contingencies and fruit and vegetable consumption as having unfavourable temporal contingencies. Support was found for the role of intention and behavioural prepotency in both behaviours, such that snacking behaviour was a joint function of intention and behavioural prepotency, and fruit and vegetable consumption was primarily a function of behavioural prepotency and secondly intention. However, self-regulation was not found to account for any additional variance in behaviour. Additionally, Allom and Mullan (2012) found that self-regulation, but not behavioural prepotency, was predictive of fruit and vegetable consumption only when participants identified as healthy eaters.

These inconsistent findings may reflect some limitations of the TST model. Specifically, categorising behaviours based on long-term benefits or consequences might be too broad as some behaviours have ambiguous temporal contingencies. Namely, behaviours such as fruit and vegetable consumption may have both short-term and long-term benefits for individuals who enjoy the taste of these foods or do not find them difficult to prepare. Therefore, the ambient temporal contingencies associated with fruit and vegetable consumption may differ according to the individual’s preferences for these foods, which is a consideration that is not accounted for in the TST. Additionally, no precise measure of behavioural prepotency has been developed and tested. Measurement of this construct often involves assessing the frequency of past behaviour or habit (Hall et al., 2008; Wong & Mullan, 2009), neither of which adequately capture the nature of behavioural prepotency, which also includes cues to action and internal drive states. Furthermore, the role of such automatic processes in the execution of health behaviours may not be adequately represented
in the TST. Recent conceptualisations of health behaviour suggest that automatic processes are just as influential in the execution of health behaviour as reflective processes, and that self-regulation influences both of these processes, rather than only intention (Hofmann, Friese, & Wiers, 2008; Strack & Deutsch, 2004). Given the limitations of the TST, alternative conceptualisations of health behaviour, and how self-regulation influences the execution of such behaviours, may offer more appropriate frameworks for understanding healthy eating behaviour.

**Dual-systems explanations**

One such conceptualisation, which recently has received much support, is the dual-systems approach to describing and explaining health behaviour. This approach highlights the role of both reflective and impulsive processes suggesting that behaviour is determined by the interaction between these two qualitatively different systems. The reflective-impulsive model (Strack & Deutsch, 2004) describes these two systems and how they guide behaviour. The reflective system represents a slow-acting and controlled system that serves to direct behaviour towards long-term goals and personal standards. Conversely, the impulsive system operates in a relatively automatic manner wherein responses to certain stimuli are derived from affective and motivational associations with these stimuli. In situations where a conflict between these two systems arises, enacting the goal-directed behaviour requires the regulation of automatic impulses, the success of which depends on individual differences in self-regulation or situational limitations on self-regulatory capacity (Fergenbaum et al., 2009). A pictorial representation of a dual-systems conceptualisation of behaviour can be seen in Figure 2.3.
As described previously, the ability to self-regulate influences the execution of health behaviours and whether intention is translated into action. According to a dual-systems approach, self-regulation not only determines the role of reflective processes on behaviour, but also determines the role of impulsive processes on behaviour. Several studies have offered support for this explanation of health behaviour. Firstly, research has demonstrated that low dispositional self-regulation determines the influence of the two systems. Honkanen, Olsen, Verplanken, and Tuu (2012) demonstrated that food-related self-control moderated the relationship between attitudes and self-reported snack consumption, such that reflective processes (i.e., explicit attitudes) predicted consumption among those with high food-related self-control, while impulsive processes (i.e., impulsive snack buying tendency) predicted

Figure 2.3. Reflective-impulsive model of goal-directed behaviour (adapted from Hofmann, Friese, & Strack, 2009).
consumption among those with low food-related self-control. Additionally, Friese and Hofmann (2009) demonstrated that among those with low trait self-control, automatic affective reactions to potato chips predicted consumption, such that those who found potato chips pleasant tended to consume more in a pseudo taste test than those who found them unpleasant. Further, impulsive processes were not predictive of consumption among those with high trait self-control. These results indicate that when self-regulation is low, due to low dispositional capacity, impulsive processes guide behaviour.

In addition to low dispositional self-regulation, certain situations and constraints may influence the ability to self-regulate. Within the strength model of self-regulation (Baumeister, Vohs, & Tice, 2007) it is posited that self-regulation relies on a limited resource which can become temporarily depleted after exertion. In the model, self-regulation is conceptualised as analogous to a muscle such that just as a muscle becomes fatigued after a period of continued exertion and has reduced capacity to exert further force, self-regulatory capacity can also become depleted when demands are made of self-regulatory resources over a period of time. This explanation of self-regulation has been supported by numerous studies, which demonstrate that engaging in a task that requires self-regulation undermines the ability to self-regulate on a secondary task (for a review, see: Hagger, Wood, Stiff, & Chatzisarantis, 2010). This phenomenon has been labelled self-regulatory depletion, or ego-depletion. It has been suggested that individuals fail to carry out health behaviours not only due to a low dispositional self-regulatory capacity but also due to an exhausted or depleted capacity (Hofmann, Friese, & Strack, 2009).

Self-regulatory depletion has been shown to result in increased consumption of tempting foods in pseudo taste tests (Gonzales et al., 2010; Kahan, Polivy, & Herman, 2003; Pierobon, Giardini, Fanfulla, Callegari, & Majani, 2008; Zyphur, Warren, Landis, & Thoresen, 2007). These results suggest than when self-regulation is depleted, individuals
experience difficulty controlling the impulse to consume unhealthy foods. Friese et al. (2008; Study 2) tested this hypothesis by measuring participants’ implicit and explicit attitudes towards an unhealthy palatable snack food (potato chips), and by manipulating self-regulatory capacity through a depletion task. Findings revealed that implicit attitudes, rather than explicit attitudes, predicted consumption in the depletion condition but not the control condition, such that depleted participants who also had positive implicit attitudes towards potato chips tended to consume more than those with negative implicit attitudes. Conversely, explicit attitudes, but not implicit attitudes, predicted consumption in the non-depleted control condition but not the depletion condition, such that non-depleted participants who reported more positive attitudes to potato chips tended to consume more than those who reported negative attitudes. Similarly, Study 1 reported in Friese et al. (2008) demonstrated differing relationships between explicit and implicit attitudes and food choice depending on whether participants had received a cognitive load manipulation. When cognitive resources were high, explicit attitude towards particular foods was the only significant predictor of choice behaviour; however, when resources were low, implicit attitude towards foods was the only significant predictor of choice behaviour. These results indicate that when self-regulatory resources are low, reflective precursors such as attitudes and healthy eating goals no longer predict behaviour. Rather, impulsive precursors such as implicit preferences for unhealthy foods direct behaviour.

Conclusions

The TPB offers an explanation of how reflective precursors influence intention formation; however, there exists a theoretical gap between intention and behaviour such that intention does not always lead to behaviour. While additional variables such as self-regulation can account for variance in behaviour and improve the prediction of behaviour from intention, models such as the TST, which incorporate these elements but still emphasise
reflective precursors, cannot account for the full range of factors that influence behaviour.

Dual-systems models which highlight the role of both reflective and impulsive processes on behaviour, and how self-regulation influences the effects of such processes, may offer a more complete account of how health behaviours are executed and may elucidate the role of self-regulation in the performance of health behaviours.
Chapter 3 – Processes underlying self-regulation: Executive functions

Dual-systems models offer an account of how self-regulation influences behaviour; however, self-regulation is not a unitary construct, as such conceptualisation and measurement of this construct varies greatly. As described in the previous chapter, self-regulation can refer to planning strategies, such as implementation intentions (Armitage, 2004), or self-monitoring techniques, such as diary keeping (Schwarzer, Antoniuk, & Gholami, 2014). Alternatively, and in the case of much of the research described in the previous chapter, self-regulation can be conceptualised as a capacity or an ability, which is determined by individual differences in higher-order cognitive processes, known as executive functions (Gazzaley & D'Esposito, 2007; Suchy, 2009). In this chapter, an overview of executive functions and their relationship to eating behaviour is presented.

Executive functions are said to subserve the capacity to self-regulate, wherein individual differences in these cognitive abilities predict the translation of reflective goals into action (Hofmann et al., 2012). Like self-regulation, executive function is a multifaceted construct; however, executive functions can be broadly thought of as falling into three categories: (1) shifting, (2) inhibitory control and, (3) updating, corresponding to the abilities to (1) flexibly alter goals and plans in response to changing contingencies, (2) inhibit goal-irrelevant information and impulses in order to maintain focus on goals and, (3) update and monitor goals (Miyake et al., 2000; Suchy, 2009). Importantly, when measured in early childhood, individual difference in executive function predicts a range of important life outcomes, including health and wealth (Marteau & Hall, 2013; Moffitt et al., 2011), and furthermore, individual differences in these constructs amongst adults have been shown to relate to the performance of numerous health behaviours (Allan, Johnston, & Campbell, 2011; Hall, 2012; Mullan et al., 2011). Generally, in terms of dual-systems approaches,
executive functions are thought to enable the goals of the reflective system to be achieved by overriding the actions of the impulsive system (Hofmann et al., 2012).

Executive functions are mainly localised in the prefrontal cortex, although the circuitry underlying these functions is complex and a number of other brain areas are also involved (Suchy, 2009). Initially executive functions were studied neurophysiologically through patients who experienced difficulty regulating their behaviour as a result of brain injury (Macmillan, 2002). However, executive functions have also been assessed in normal populations through technologies such as functional magnetic resonance imaging (Luna & Sweeney, 2004; Osaka et al., 2004), psychometric assessments (Patton & Stanford, 1995; Strathman, Gleicher, Boninger, & Edwards, 1994), and a variety of behavioural paradigms or tasks that tax particular facets of executive function (Suchy, 2009). While neurophysiological measures offer a precise examination of the brain regions and processes involved in executive function, these methods are beyond the scope and means of this thesis and will not be utilised.

Psychometric assessments such as scales measuring trait self-control (Tangney, Baumeister, & Boone, 2004), temporal orientation (Strathman et al., 1994), and impulsivity (Patton & Stanford, 1995) have been used to assess executive function in the context of health behaviour. For example, the Barratt impulsiveness scale (Patton & Stanford, 1995), has been applied to the prediction of both saturated fat intake and fruit and vegetable consumption. Mullan et al. (2014) found that higher levels of impulsiveness were associated with greater saturated fat intake; however; individual differences in impulsiveness were not related to fruit and vegetable consumption. Psychometric scales such as the Barratt impulsiveness scale offer a broad indication of how executive function relates to health behaviours; however, these measures are limited in that they rely on the reporting of an ability that may not be consciously accessible (Duckworth & Kern, 2011). Tasks that tax
particular elements of executive function have also been used to assess these processes and may offer a more precise measure of executive function (Suchy, 2009). Indeed, a meta-analysis comparing self-report measures of executive function to behavioural tasks found that there was little overlap between these methods (Cyders & Coskunpinar, 2011). Specifically, it has been suggested that behavioural tasks are more precise as they: (a) tend to be designed to maximise sensitivity and specificity to discrete aspects of executive function, (b) generate normally distributed scores, and (c) are relatively resistant to previously learned skills (Suchy, 2009). In the remainder of this chapter, examples of these tasks are described, and evidence linking performance on these tasks to eating behaviour is reviewed.

**Shifting**

Shifting refers to the ability to move back and forth between different tasks or mental sets in order to achieve a goal or a certain end state (Monsell, 1996). Additionally, this process involves the disengagement of task sets that have become irrelevant, or no longer serve a long-term goal, and the subsequent active engagement of a relevant task set (Allport & Wylie, 2000). Tasks that measure this capacity include the Wisconsin card sorting task (WCST; Grant & Berg, 1948), and the trail making task (TMT; Reitan, 1958). These tasks both reflect the ability to regulate behaviour in changing environments in which previous responses are no longer appropriate to the attainment of long-term goals (Spiro, Feltovich, Jacobson, & Coulson, 1992).

In the WCST, participants are required to match a stimulus card to one of four options based on one of three properties: symbol on card, colour of symbol, or number of symbols. Once the rule has been solved correctly four times in a row, the property by which the cards are to be sorted changes. The variable of interest is the number of ‘perseverance’ errors. Such errors occur when the rule has changed yet participants continue to respond in a way that is appropriate to the previous rule, rather than the new rule. A lower number of errors indicates
superior shifting ability (Grant & Berg, 1948). See Figure 3.1 for a depiction of the WCST. In the TMT participants draw consecutive lines between numbers (part A: numbers 1 through 25), and then numbers and letters (part B: alternating between numbers 1 through 13 and letters A through L), as fast as possible. Shifting ability is indexed as the total time in seconds to complete part B minus the time to complete part A (Reitan, 1958). Subtracting the time taken to complete part A from part B allows the calculation of shifting time, while controlling for individual differences in drawing time. See Figure 3.2 for a depiction of the TMT. Studies of non-clinical populations show that these task have good test-retest reliability (Giovagnoli et al., 1996), and can indicate individual differences in cognitive function (Wang, Kakigi, & Hoshiyama, 2001). A meta-analysis of neuroimaging studies and the WCST revealed distributed fronto-parietal activation patterns consistent with the status as a shifting task (Buchsbaum, Greer, Chang, & Berman, 2005). Similarly, the TMT has been shown to tax an ability that is independent of visual-motor abilities (i.e., shifting; Oliveira-Souza et al., 2000).

Figure 3.1. Wisconsin card sorting task. In this example, card 5 can be matched to one of the above based on one of three properties: colour (card 3), shape (card 4) or number of shapes (card 2).
The ability to shift between responses in order to adapt to changing environments may be particularly relevant for the execution of healthy eating behaviour. For example, habitual consumption of unhealthy foods may be seen as a reflection of an inability to generate and initiate responses that are appropriate to the current situation (Monsell, 2003). Additionally, given that shifting also reflects the ability to overcome proactive interference (Allport & Wylie, 2000), individuals with a superior shifting ability may be able to successfully ignore cues in the environment that trigger unhealthy eating behaviour. Indeed, studies have shown an association between BMI and shifting ability, such that those with an extreme BMI (i.e., underweight or obese individuals) tend to perform poorer on the WCST and the TMT (Roberts, Demetriou, Treasure, & Tchanturia, 2007; Roberts, Tchanturia, Stahl, Southgate, &
Specifically, both underweight and obese participants demonstrate less abstraction ability and flexibility of thought than normal-weight or overweight participants (Gunstad et al., 2007).

Research exploring the association between shifting capacity and eating behaviour between normal-weight to obese individuals is summarised in Table 3.1. Concerning differences between normal-weight and obese individuals, a systematic review of 21 studies examining the relationship between weight and impairment on shifting tasks indicated that overall, obese individuals tend to demonstrate consistently impaired performance on the WCST (Fitzpatrick, Gilbert, & Serpell, 2013); however, the relationship between TMT and weight appeared to be less consistent. Limited research has examined whether individual differences in shifting capacity in normal-weight populations relate to eating behaviours including saturated fat intake and fruit and vegetable consumption. In one study, Allan et al. (2011) demonstrated that superior performance on a combination of shifting measures, including the TMT, explained variance in the intention-behaviour gap for both snacking behaviour and fruit and vegetable consumption. While these results appear to demonstrate a link between shifting ability and the eating behaviour of normal-weight adults, the majority of research appears to suggest that shifting deficits are primarily involved in the eating behaviour of underweight or obese individuals. For this reason, and due to the resource constraints of a PhD project, shifting ability will not be focused on in this thesis.
<table>
<thead>
<tr>
<th><strong>Normal-weight participants</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Allan et al. (2011; Study 1)</td>
<td>Shifting factor (TMT, Tower task, and verbal fluency task) explained 16% of the variance in the intention–behaviour gap for FV and explained 16% of the variance in the intention–behaviour gap for snacking</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Obese versus normal-weight controls</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Boekka and Lokken (2008)</td>
<td>Obese individuals performed poorly on WCST. No differences on TMT performance between obese and NW</td>
</tr>
<tr>
<td>Cserjési et al. (2009)</td>
<td>Women with obesity performed significantly worse on TMT than NW</td>
</tr>
<tr>
<td>Fagundo et al. (2012)</td>
<td>Obese participants performed significantly worse on the WCST compared to NW</td>
</tr>
<tr>
<td>Fergenbaum et al. (2009)</td>
<td>BMI was associated with reduced shifting ability: obese individuals had a fourfold risk of impaired performance on TMT compared to overweight or NW</td>
</tr>
<tr>
<td>Gonzales et al. (2010)</td>
<td>Obese BMI group displayed significantly less TMT task-related activation in the right parietal cortex</td>
</tr>
<tr>
<td>Gunstad et al. (2007)</td>
<td>Overweight and obese individuals performed poorer on TMT relative to NW</td>
</tr>
<tr>
<td>Roberts et al. (2007)</td>
<td>Performance on TMT and WCST did not differ between overweight and NW</td>
</tr>
<tr>
<td>Volkow et al. (2009)</td>
<td>Performance on WCST positively correlated with BMI</td>
</tr>
</tbody>
</table>

*Note.* BMI = body mass index; FV = fruit and vegetable consumption; NW = normal-weight control; TMT = trail making task; WCST = Wisconsin card sorting task
**Inhibitory control**

Inhibitory control refers to the ability to purposely override dominant, automatic, or prepotent responses when required in order to achieve a goal. Inhibitory control is mainly assessed using behavioural tasks such as the Stroop interference task (Stroop, 1935), stop-signal task, (SST; Logan, Schachar, & Tannock, 1997), and the go/no-go task (GNG; Miller, Schäffer, & Hackley, 1991). These tasks all share the requirement to inhibit the processing of a bottom-up, inappropriate response. These tasks have been shown to demonstrate good internal consistency and test-retest reliability within healthy participants (Kindlon, Mezzacappa, & Earls, 1995; Soreni, Crosbie, Ickowicz, & Schachar, 2009; Wostmann, Aichert, Costaa, Rubiab, & Mollera, 2013). Additionally, latent variables analyses suggest that there is a common, domain-general inhibitory control mechanism involved across all inhibitory tasks (Brocki & Bohlin, 2004; Friedman & Miyake, 2004), which contributes to many higher-order cognitive abilities including abstract reasoning, the resolution of complex problems, and decision making (Chiappe, Hasher, & Siegel, 2000; Handley, Capon, Beveridge, Dennis, & Evans, 2004; Viskontas, Morrison, Holyoak, Hummel, & Knowlton, 2004). Individual differences in performance on these tasks have been used to predict numerous health behaviours including eating behaviour (Allan et al., 2011; Hall, 2012), and smoking behaviour, substance use and sleep habits (Hall, Elias, & Crossley, 2006).

Specifically, in the Stroop task, participants are required to name the colour in which a written colour word is printed while inhibiting the tendency to read the word itself. Inhibitory control is required when the colour in which the word is printed, and the word itself, are incongruent. For example, when the word ‘red’ is printed in blue, the tendency to respond ‘red’ must be inhibited in order to provide the correct response of ‘blue’. Inhibitory control is usually measured as the time taken to respond correctly on such ‘incongruent’ trials compared to the time taken to respond correctly on congruent trials or control trials.
MacLeod, 2005). The greater the mean difference between trials, the poorer inhibitory control is said to be. An example of the trials and correct responses required on the Stroop task is displayed in Figure 3.3.

![Figure 3.3. The Stroop interference task. Congruent trials: the meaning of the word and the colour in which it is printed match. Incongruent trials: the meaning of the word and the colour in which it is printed do not match. Control: String of letters printed in a colour.](image)

In the SST, participants are required to categorise a set of stimuli as quickly as possible, unless a signal to stop responding is presented, at which point participants must inhibit their on-going response (Verbruggen & Logan, 2008). The delay between the presentation of the stimulus and the stop-signal influences the probability of stopping the on-going response. Specifically, the longer the delay between the stimulus and the stop-signal, the lower the probability of successfully inhibiting an on-going response. SST performance is usually indexed by stop-signal reaction time; an estimation of the time taken to stop the on-
going response once the signal has been presented (Logan, 1994). A smaller stop-signal reaction time indicates greater inhibitory control. In contrast, the GNG requires participants to respond as rapidly as possible to one set of stimuli (go) while consistently withholding responses to another set (no-go). The number of false alarms: responses to no-go stimuli, and reaction times to go stimuli are used as an index of inhibitory control (Miller et al., 1991). The tasks differ in that in the GNG all responses to a particular set of stimuli must be inhibited, whereas in the SST only a proportion of responses to a particular set of stimuli must be inhibited or cancelled. A depiction of the SST and the GNG is displayed in Figure 3.4.

Figure 3.4. The stop-signal task and go/no-go task. In the stop-signal task, participants must respond to all stimuli unless a stop-signal is presented, at which point they must withhold their response. In the go/no-go task, participants respond to all stimuli in a category (i.e., any letter besides X) and withhold responses to all others (i.e., X)
Inhibitory control and eating behaviour

In the case of healthy eating, the ability to inhibit a prepotent or on-going response is essential. Specifically, in order to meet the goal of adhering to a healthy diet one must inhibit the desire to consume unhealthy palatable foods. Previous research investigating the role of inhibitory control in eating behaviour has demonstrated that deficits in performance on inhibitory control measures are associated with poorer eating behaviour and weight gain (Nederkoorn et al., 2010). Research examining the association between inhibitory control and eating behaviour is summarised in Table 3.2. Specifically, Allan et al. (2010) demonstrated that poorer Stroop performance was associated with greater chocolate consumption in those who intended to avoid high-calorie food, suggesting that inhibitory control is necessary to carry out healthy eating goals. Further, research examining the relationship between SST and eating behaviour has demonstrated that those who performed poorer on the SST, and who had strong implicit preferences for snack food, gained the most weight over a year, suggesting that inhibitory control is necessary to regulate impulses towards palatable foods (Nederkoorn et al., 2010). Regarding inhibitory control as measured by the GNG, Hall (2012) and Hall et al. (2008) found an association between GNG performance and eating behaviour, such that those higher in inhibitory control were more likely to carry out their intentions to eat healthily. These findings suggest that inhibitory control plays a major role in the regulation of eating behaviour, such that deficits in inhibitory control contribute to the consumption of unhealthy foods, and ultimately, to weight gain.

Experimental research linking inhibitory control with eating behaviour has found that priming of inhibitory control, versus impulsivity, leads to less consumption of unhealthy foods in an immediately administered pseudo taste test (Guerrieri et al., 2009; Guerrieri, Nederkoorn, Stankiewicz, et al., 2007; Rotenberg et al., 2005). For example, Guerrieri et al. (2009) demonstrated that participants who read a story in which the intentions to study for
exams and to save money were stated, consumed significantly less than those who read an opinion in which the importance of flexibility and spontaneity was stated. The results indicated that priming thoughts of inhibitory control versus thoughts of impulsivity was sufficient to result in differences in eating behaviour. Moreover, these results indicate the causal role that inhibitory control plays in regulating eating behaviour, suggesting that it may be a useful construct to target in interventions designed to improve eating behaviour.
Table 3.2

*Summary of Studies Examining the Relationship between Inhibitory Control and Eating Behaviour*

<table>
<thead>
<tr>
<th>Normal-weight participants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Allan et al. (2011; Study 1)</strong></td>
</tr>
<tr>
<td><strong>Allan et al. (2011; Study 2)</strong></td>
</tr>
<tr>
<td><strong>Allan et al. (2010)</strong></td>
</tr>
<tr>
<td><strong>Collins and Mullan (2011)</strong></td>
</tr>
<tr>
<td><strong>Guerrieri et al. (2009)</strong></td>
</tr>
<tr>
<td><strong>Hall (2012)</strong></td>
</tr>
<tr>
<td><strong>Hall et al. (2008)</strong></td>
</tr>
<tr>
<td><strong>Hofmann, Friese, and Roefs</strong></td>
</tr>
</tbody>
</table>
who performed poorly on the SST

Jasinska et al. (2012) Weak negative relationship between GNG performance and *tasty-healthy* choices; no relationship between GNG performance and *tasty-unhealthy* choices

Nederkoorn et al. (2010) Females with strong implicit preferences for snack food (IAT), and poorer performance on the SST, gained the most weight over a year; performance on SST directly predicted weight gain

<table>
<thead>
<tr>
<th><strong>Obese versus normal-weight controls</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fagundo et al. (2012)</strong></td>
</tr>
<tr>
<td><strong>Gunstad et al. (2007)</strong></td>
</tr>
<tr>
<td><strong>Hendrick et al. (2011)</strong></td>
</tr>
<tr>
<td><strong>Loeber et al. (2012)</strong></td>
</tr>
<tr>
<td><strong>Mobbs et al. (2011)</strong></td>
</tr>
<tr>
<td><strong>Nederkoorn et al. (2006)</strong></td>
</tr>
</tbody>
</table>

*Note.* BMI = body mass index; FV = fruit and vegetable consumption; GNG = go/no-go task; IAT = implicit association task; NW = normal-weight controls; SST = stop-signal task
Updating

Updating is closely related to working memory and refers to the ability to keep goal-relevant information in an active, quickly retrievable state, and to shield this information from distraction (Miyake et al., 2000). Updating has been measured using tasks including the $n$-back (Jaeggi et al., 2010) and the operation span task (OSPAN; Kane, Conway, Miura, & Colflesh, 2007). Both of these tasks require the ability to maintain information in working memory while simultaneously performing distracting or interfering activities (Cantor & Engle, 1993; Daneman & Carpenter, 1980). These tasks have also been shown to demonstrate acceptable test-retest reliability (Beckmann, Holling, & Kuhn, 2007). Additionally, these tasks have been shown to predict inter-individual differences in other higher cognitive functions, such as fluid intelligence (Jaeggi et al., 2010), and reasoning (Kane et al., 2007), which are related to a variety of health outcomes including eating behaviour (Batterham, Christensen, & Mackinnon, 2009; Gottfredson & Deary, 2004).

In the $n$-back, a sequence of stimuli is presented and participants must indicate when the current stimulus matches one $n$ steps earlier in the sequence. Working memory needs to be updated with each new presentation to monitor to what the current stimulus needs to be compared. Updating performance is assessed in terms of the proportion of hits minus false alarms and reaction times for correct responses only (Snodgrass & Corwin, 1988). See Figure 3.5 for a depiction of the $n$-back task. The OSPAN involves confirming the correctness of mathematical equations while keeping a letter string active in working memory. This letter string must be updated with each new presentation and recalled in the correct order when prompted. Updating is assessed as the number of correctly recalled strings of letters (Turner & Engle, 1989). See Figure 3.6 for a depiction of the OSPAN.
Figure 3.5. $N$-back with examples of 1-, 2-, and 3- back. Participants have to indicate whether the current stimulus matches the stimulus that preceded it $n$ steps back in the sequence.
Updating and eating behaviour

The ability to maintain and manipulate goal-relevant information is essential to the performance of goal-directed behaviours. In the case of healthy eating, updating may be necessary to ensure that the goal to eat healthily is active and retrievable when faced with unhealthy choices. Specifically, Hege et al. (2013) demonstrated that the ability to monitor previous food intake and current food cues, which indicate subsequent available food, is of crucial importance for successful regulation of food intake and weight maintenance.
Additionally, neuroimaging studies have demonstrated that regions involved in the formation of neuronal object representations (Bell, Hadj-Bouziane, Frihauf, Tootell, & Ungerleider, 2009; Konen & Kastner, 2008; Riesenhuber & Poggio, 2002), and the maintenance of objects in working memory (Curtis & D'Esposito, 2003; Osipova et al., 2006), are also crucial for controlling eating behaviour. For example, the dorsolateral region of prefrontal cortex has been shown to demonstrate increased activation following the ingestion of a meal (Gautier et al., 2001). Further, research has also shown that successful weight maintainers demonstrate increased activation in these areas, compared to those who are unable to maintain weight (DelParigi et al., 2007). These results suggest that neuronal pathways specifically involved in updating are also involved in the regulation of eating behaviour.

Research examining the relationship between updating capacity and eating behaviour is summarised in Table 3.3. For normal-weight participants, it has been shown that manipulation of the memory for the most recent meal affects subsequent food intake, suggesting that the ability to maintain information about recent food intake in working memory determines current decisions about food consumption (Higgs, Rutters, Thomas, Naish, & Humphreys, 2012). In an obese sample, Hege et al. (2013) found that poorer performance on an n-back task, which included food stimuli, was related to poorer weight outcomes in a lifestyle intervention. These results suggest that the ability to encode or retrieve representations of food and weight loss goals may contribute to the regulation of eating behaviour. In terms of studies using the OSPAN, Hofmann, Friese, and Roefs (2009) and Hofmann, Gschwendner, Friese, Wiers, and Schmitt (2008) demonstrated that implicit attitudes towards chocolate, rather than explicit dietary goals, predicted chocolate consumption within individuals who performed poorly on this task. Conversely, amongst those who performed better on the task, the goal to forgo sweets predicted behaviour, rather than implicit attitudes (Hofmann, Gschwendner, et al., 2008). These results indicate the
importance of updating ability in the regulation of eating behaviour, suggesting that having a
goal to eat healthily may only be beneficial when an individual has sufficient ability to
maintain and update this goal. This assumption is similar to the findings of Allan et al. (2013)
in which goals were only predictive of behaviour amongst those with sufficient planning
ability. Finally, experimental research has demonstrated that when updating ability is
impeded, implicit preferences direct food choice (Friese et al., 2008), suggesting that, like
inhibitory control, updating may play a causal role in eating behaviour and thus may provide
a target for intervention design.
<table>
<thead>
<tr>
<th>Study Reference</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hege et al. (2013)</td>
<td>Food-tailored 1-back performance predicted weight outcomes in weight loss intervention</td>
</tr>
<tr>
<td>Higgs et al. (2012)</td>
<td>Attention of NW participants was drawn to food cues when cues were specifically held in working memory (not just attended to), suggesting that individuals who are preoccupied with thoughts of food (e.g., obese) show facilitated detection of food cues in environment</td>
</tr>
<tr>
<td>Friese et al. (2008; Study 1)</td>
<td>Explicit attitudes predicted food choice (chocolate versus fruit) in those with working memory resources; implicit attitudes (IAT) predicted food choice in those with compromised working memory resources</td>
</tr>
<tr>
<td>Hofmann, Gschwendner, et al. (2008; Study 2)</td>
<td>Implicit preferences for snack food (IAT) predicted chocolate consumption (pseudo taste test) in females who performed poorly on the OSPAN; goal to forgo sweets predicted behaviour for females who performed better on the OSPAN</td>
</tr>
<tr>
<td>Hofmann, Friese, and Roefs (2009)</td>
<td>Automatic affective reactions for chocolate (IAT) predicted chocolate consumption (pseudo taste test) in participants who performed poorly on the OSPAN</td>
</tr>
<tr>
<td>Kalmijn et al. (2004)</td>
<td>A cross-sectional study of a middle-aged population demonstrated that SF was associated with increased risk of impaired cognitive functions, including verbal memory</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Summary</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Kang, Ascherio, and Grodstein (2005)</td>
<td>Fruit intake was not associated with cognition or cognitive decline. However, total vegetable intake was significantly associated with less cognitive decline.</td>
</tr>
<tr>
<td>(Kesse-Guyot et al., 2011)</td>
<td>Better adherence to nutritional recommendations was significantly associated with verbal memory.</td>
</tr>
<tr>
<td>Okereke et al. (2012)</td>
<td>Higher SF was associated with poor global cognitive outcomes, and verbal memory.</td>
</tr>
<tr>
<td>Péneau et al. (2011)</td>
<td>FV and fruit consumption alone were positively associated with verbal memory scores.</td>
</tr>
<tr>
<td>Sabia et al. (2009)</td>
<td>Poorer executive function and memory were associated with engagement in a greater number of unhealthy behaviours including unhealthy eating behaviour (self-report) over 17 years.</td>
</tr>
<tr>
<td>Shaw and Tiggemann (2004)</td>
<td>Dieters demonstrated a specific working memory impairment, suggesting that poorer working memory are associated with preoccupying thoughts about food and weight.</td>
</tr>
<tr>
<td>Stingl et al. (2012)</td>
<td>Performance on a food tailored 1-back correlated with BMI.</td>
</tr>
<tr>
<td>Wald et al. (In press)</td>
<td>College students who adhere to public health recommendations for lifestyle behaviours, including FV, have modestly higher grade averages after adjusting for socio-demographic and negative health behaviours.</td>
</tr>
</tbody>
</table>

**Note.** BMI = body mass index; FV = fruit and vegetable consumption; IAT = implicit association task; NW = normal-weight controls; OSPAN = operation span task; SF = saturated fat intake.
Conclusions

In this chapter, the processes underlying self-regulation were discussed with particular focus on how these processes relate to eating behaviour. While there appears to be a link between shifting ability and the eating behaviour of obese participants, there is limited research suggesting that individual differences in shifting ability are related to the eating behaviour of normal-weight participants. However, the regarding inhibitory control and updating appeared to indicate a stronger connection between these facets of executive function and the eating behaviour of normal-weight participants. Specifically, participants who perform poorly on measures of inhibitory control or updating also have difficulty regulating their eating behaviour. The majority of studies examining the relationship between executive function and eating behaviour tend to focus on the prediction of unhealthy eating behaviours, rather than the prediction of healthy eating behaviours, such as fruit and vegetable consumption. Given that fruit and vegetable consumption plays an important role in health outcomes and weight maintenance, research into whether certain facets of executive function are related to these behaviours is warranted.
Chapter 4 – How do healthy eaters describe their ability to self-regulate? A qualitative analysis

According to dual-systems theories, unhealthy eating behaviour arises when the impulse to consume unhealthy foods outweighs the long-term goal of consuming a healthy diet (Hofmann, Friese, & Roefs, 2009). The literature review presented in the previous chapters makes clear that the ability to self-regulate plays an important role in achieving healthy eating goals and that categories of higher-order cognitive processes underlie this ability. However, while the role of self-regulation in regulating eating behaviour has been assessed using self-report scales of related facets such as impulsiveness (Mullan et al., 2014), and/or behavioural tasks said to objectively measure such facets (Hofmann, Friese, & Roefs, 2009), little is known about individuals’ perceptions of self-regulation and how this might influence behaviour. For example, it has been proposed that viewing self-regulation as either a limited or a non-limited resource influences the ability to self-regulate (Job, Dweck, & Walton, 2010). In this chapter, the results of a focus group analysis of young adults’ perceptions of healthy eating and experiences of how they regulate this behaviour are presented.

Eating behaviour of young adults

Research indicates that young adults are at a particularly high risk for weight gain (Must, Gortmaker, & Dietz, 1994). The Australian Diabetes, Obesity and Lifestyle study found that young adults aged 25 - 34 years had experienced the greatest increase in weight, waist circumference and BMI between 2000 and 2005 compared to all other age groups examined (Barr et al., 2006). This is consistent with data collected overseas (Gordon-Larsen, Nelson, & Popkin, 2004; Must et al., 1994). Importantly, it has been shown that being only
slightly overweight during young adulthood contributes to the incidence of obesity by the mid-30s (Guo et al., 2000; Must & Strauss, 1999).

The increased risk of weight gain faced by young adults has been attributed to a variety of personal and lifestyle challenges that are common to young adults (Racette, Deusinger, Strube, Highstein, & Deusinger, 2005). These challenges primarily arise from the need to adjust to new surroundings and workloads. Personal factors include higher levels of disordered eating (Wittchen, Nelson, & Lachner, 1998), and more unrealistic weight goals compared to other age groups (Crawford & Campbell, 1999). Lifestyle factors include increased socialising with peers (Strong, Parks, Anderson, Winett, & Davy, 2008), which usually leads to greater consumption of high-calorie food and alcohol (McCarty et al., 2009). The university lifestyle also impacts upon weight management as students believe themselves to have limited time to prepare healthy meals and to consume appropriate amounts of fruit and vegetables (Leslie, Sparling, & Owen, 2001).

Examining the eating behaviour of healthy individuals

The majority of research that examines the barriers to and the enablers of healthy eating behaviour has focused primarily on overweight or obese individuals. Recently, emphasis has been placed on the usefulness of examining the cognitions and behaviours of those who are successful at maintaining a healthy weight, rather than concentrating wholly on overweight or obese individuals (de Ridder, 2012). Findings from studies examining eating behaviour in a healthy population have indicated that a variety of factors influence the execution of healthy eating behaviour indicating self-regulation (Allom & Mullan, 2012). Additionally, situational factors that influence the ability to self-regulate have also been implicated as important in the uptake and maintenance of healthy eating behaviour. Namely, the accessibility of unhealthy foods in the environment, and cues to consume such foods,
have been identified as major contributors to unhealthy eating behaviour (Maas, de Ridder, de Vet, & de Wit, 2012).

Cues in the environment such as sight, smell, and taste of palatable food trigger the desire to consume food based on anticipated pleasure rather than hunger (Wansink, 2004). From a dual-systems perspective these cues facilitate the impulsive system rather than the reflective system. For example, Harris, Bargh, and Brownell (2009) demonstrated that viewing television advertisements for unhealthy foods compared to advertisements promoting healthy foods influenced the consumption of products that were not presented in the advertisements. Participants who viewed advertisements for unhealthy foods consumed more food during a pseudo taste test compared to those who viewed healthy advertisements regardless of hunger level or ratings of the healthiness of foods. These results demonstrate that cues to eat unhealthily have a significant influence on consumption and may compromise the ability of the reflective system to direct behaviour. According to the reflective-impulsive model, self-regulation would moderate the influence of cues to action on eating behaviour such that the behaviour of those with a greater self-regulatory capacity would be less affected by these cues (Hofmann, Friese, et al., 2008). However, it is unclear exactly how self-regulation is employed to cope with such triggers. For example, it may be the case that having a strong self-regulatory capacity renders these cues less salient, or perhaps particular strategies are engaged that lessen the negative impact of cues to action. Therefore, qualitatively exploring the experiences of successful healthy eaters may elucidate the nature of the role of self-regulation in eating behaviour.

Chambers and Swanson (2011) conducted a series of interviews exploring the experiences, successes and difficulties with weight control of individuals who had either maintained the same weight since age 18, had lost weight and were now maintaining that weight, or who had gained weight since age 18. Interestingly, there appeared to be
differences in responses to weight gain and coping strategies between these groups. Namely, maintainers tended to monitor weight fluctuations, be vigilant in response to weight gain by taking immediate action, and coped with setbacks by increasing effort. This was in comparison to unsuccessful weight maintainers who monitored weight gain in an erratic or inconsistent manner, only took action when in the right mindset to do so and perceived setbacks as failures. While this research was informative in terms of weight maintenance, factors leading to unhealthy eating behaviour were not specifically targeted, nor were individuals’ perceptions regarding their ability to regulate their eating behaviour. Furthermore, it is unclear whether these findings are generalisable to a younger adult population given that the participants in this study were all above 30 years of age.

**Aims**

Given that previous research has focused on those who are unable to regulate their eating behaviour, the aim of the present study was to qualitatively explore the perceptions and experiences of a population of normal-weight individuals who perceived themselves to eat healthily, in order to provide insight into how these individuals are able to successfully maintain healthy eating behaviour. Specifically, the aim of this research was to explore the barriers to healthy eating faced by these individuals, and to determine the means by which healthy eaters successfully overcome these barriers. These factors have the potential to inform future quantitative research and develop alternatives to current interventions in young people which are generally not successful in supporting healthy eating maintenance (Hebden, Chey, & Allman-Farinelli, 2012).

Focus groups were used due to the exploratory nature of the study. This qualitative method of enquiry allows participants to interact with each other, compare and contrast opinion and talk more freely than an individual interview allows (Rice & Ezzy, 1999). Furthermore, qualitative research methodology has been shown to be an effective method for
gathering information about the processes governing food choice among other populations, such as within families (Hesketh, Waters, Green, Salmon, & Williams, 2005; Ip, Mehta, & Coveney, 2007) and adolescents (Croll, Neumark-Sztainer, & Story, 2001; Jenkins & Horner, 2005).

Methods

Participants

Forty-one participants enrolled in the study and provided weight status information. One participant who was classed as underweight (BMI = 17.05) was excluded, debriefed and provided with information regarding healthy weight and counselling services. Five participants did not attend, leaving 35 participants (4-6 in each group; 7 groups in total). The mean BMI of the remaining sample was 21.47 (SD = 1.53). No participant indicated having an eating disorder in the past or present. The mean age of participants was 19.46 years (SD = 2.31), 68.6% identified as being Australian (n = 24), 31.4% identified as Asian (n = 11), and the majority of the sample was female (71.4%; n = 25).

Procedure

The study was approved by the University Human Research Ethics Committee (see Appendix A). Participants enrolled in a variety of undergraduate courses at an Australian university were recruited using an online registration system and participated for course credit. All participants gave their informed consent before providing self-reported demographic information. Those who were 18 years or older, considered themselves to be healthy eaters, had maintained a healthy weight as an adult; as indicated by a BMI between 18.50 and 24.99, and indicated no current or prior eating disorders were then invited to join a focus group. Participants self-selected the focus group they wished to attend from a list of available days. Participants were briefed at the onset that no idea was considered trivial or
wrong. Once a participant expressed an idea, others were encouraged to expand further. Each issue was discussed until exhaustion of that idea. Focus groups were conducted until no new ideas were generated and thus saturation had been reached (Francis et al., 2010). In order to ensure consistency of data gathering, the first researcher facilitated all focus group sessions. Moderator involvement was low-to-medium in order to focus the discussion but also to allow participants’ to communicate their perspectives freely (Kitzinger & Barbour, 1999). During the session, notes were made of non-verbal communication expressed by participants that related to the content of the conversation, for example, nods of agreement. Sessions lasted approximately one hour and took place from 2pm to 3pm weekdays on the university campus. Debriefing took place immediately after each session.

**Measures**

Each focus group session was guided by a semi-structured interview schedule. This method was employed to ensure consistency in questions asked across groups, yet allow for some flexibility in accordance with topics raised within the group. The questions with probes for the focus groups were developed according to the Krueger and Casey (2009) method of five categories of questions. The first category involved an opening or warm-up question, which was designed to acquaint participants ("Tell us your name and your favourite food."). Following this, an introductory question was asked which began discussion of the topic and allowed participants to express their understanding of the phenomenon under investigation ("Describe a healthy diet/weight."). Transition questions were used to move smoothly and seamlessly into and between key questions and to help participants envision the topic in a broader scope ("Describe your eating behaviour"). Key questions were designed to obtain insight into areas of central concern in the study ("What enables/impedes the maintenance of your healthy eating behaviour? Prompt: Routine, internal states, particular situations. Describe particular successes or struggles you’ve encountered while trying to eat healthily.")
Prompt: maintaining focus on healthy eating goal, self-control”). Finally, a concluding question was asked to help researchers determine where to place emphasis and bring closure to the discussion (“We are interested in how healthy eaters differ from unhealthy eaters, what advice do you have for us?”). See Appendix B for full interview schedule.

Questions were informed by social-cognitive models of health behaviour that have been used in the health psychology literature to predict behaviour including healthy eating (Conner, Norman, & Bell, 2002; Deshpande, Basil, & Basil, 2009). For example, key questions were concerned with facilitators to action and barriers to action (Shepherd et al., 2006). Specific prompts, such as social influences (Conner et al., 2002), and cues to action (Hall & Fong, 2007), were also drawn from this literature.

The questions were reviewed for content validity by the supervisor, and modifications were made. The interview schedule was tested on a pilot focus group to determine the appropriateness of questions for eliciting responses to the target issues, and for length of time of the focus group discussion. The data from the pilot group were not included in the analysis. Following the pilot group, the interview schedule was modified appropriately.

Coding

Sessions were audio taped and transcribed verbatim. The transcripts were entered into NVivo 9 (QSR International, 2010), a software program used to assist with storage, coding and searching of data. The transcripts were reviewed line-by-line for concepts, themes and ideas, and developed a preliminary coding scheme. The coding scheme was based on the previously described literature search and included: facilitators of healthy eating, barriers to maintaining healthy eating, and perspectives on self-regulation and the role of environment. Transcripts were read and coded by the student and the supervisor independently, who then compared and discussed their individual coding choices. Any disagreements were resolved by discussion. Following this, a thematic framework was created which involved determining
the primary themes as well as the secondary themes that fell within these primary categories. Themes were developed based on ideas expressed and agreed upon by more than one person within the group. Ideas expressed by a single participant that were not agreed nor built upon by other members of the focus group were not identified as themes. The themes were discussed and agreed upon by the student and supervisor.

Results

Four themes were identified that represented the healthy eating experiences and perceptions of normal-weight young adults. A summary of themes is presented in Table 4.1. Primary and secondary themes are reported in the following sections and representative quotes from each theme are presented in Tables 4.2-4.5.
Table 4.1

*Themes by Focus Group Session*

<table>
<thead>
<tr>
<th>Focus group session</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>n</em></td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Sex (F, M)</td>
<td>3, 2</td>
<td>4, 1</td>
<td>3,1</td>
<td>3,3</td>
<td>5,0</td>
<td>5,1</td>
<td>2,2</td>
</tr>
<tr>
<td><strong>Theme</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy eating enablers and barriers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-regulation</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Success as a facilitator and inhibitor</td>
<td>—</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>—</td>
<td>Y</td>
<td>—</td>
</tr>
<tr>
<td>Cognitive framing</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>—</td>
<td>—</td>
<td>Y</td>
</tr>
<tr>
<td>Peers as a facilitators and inhibitors</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Coping with environmental barriers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of high-calorie foods</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Cues to action</td>
<td>Y</td>
<td>—</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Nature of self-regulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited versus non-limited resource</td>
<td>Y</td>
<td>Y</td>
<td>—</td>
<td>—</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Carry-over effects</td>
<td>—</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Planning and monitoring</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Habit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing automaticity</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Breaking routine</td>
<td>Y</td>
<td>—</td>
<td>Y</td>
<td>—</td>
<td>—</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

*Note.* Y = discussed in focus group.
Healthy eating enablers and barriers

Self-regulation. Self-regulation, described as ‘self-control’, ‘willpower’, and ‘dedication’, was consistently noted as a necessary determinant of healthy eating. See Table 4.2 for representative quotes relating to this theme. Participants clearly attributed their success, at maintaining healthy eating behaviour, to higher-order cognitive processes. Particularly, focusing on the long-term goal of achieving a healthy lifestyle, rather than the short-term goal of seeking gratification from the consumption of high-calorie foods, was described as an enabler to healthy eating. Participants speculated that unhealthy eaters find this task more difficult than they do, and are thus more likely to abandon their healthy eating goals.

Success as a facilitator or inhibitor. A factor that was seen to be both a facilitator, and an inhibitor of healthy eating, was perceived success. Success could refer to either losing/maintaining weight or adhering to a healthy diet. Participants described that experiencing success facilitated healthy eating behaviour as the goal became achievable and salient, whereas not perceiving any result was discouraging and led to abandonment of healthy eating behaviour. Participants also discussed how experiencing success may be detrimental in that it provided a license to return to previous unhealthy eating behaviours. This was sometimes associated with cycling between dieting and over-indulging. However, healthy eaters in this sample appeared be somewhat resilient to these setbacks and expressed optimism in the face of these challenges.

Cognitive framing. The ability to maintain healthy eating behaviour was attributed to the way in which this goal was cognitively framed. Participants described their healthy eating behaviour as part of an ongoing healthy lifestyle rather than a temporary diet, which they saw as instrumental in improving the likelihood of maintenance. Correspondingly, participants
held negative opinions towards dieting and all agreed that such short-term measures inevitably led to failure.

Peers as facilitators or inhibitors. Participants in all focus groups indicated that their ability to regulate their eating behaviour often depended on the actions, opinions, and attitudes of others. Participants agreed that if someone close to them, such as a friend, was trying to improve their dietary behaviour, they would feel more encouraged to regulate their eating behaviour. However, if their friend reverted back to eating unhealthily, this support was lost and participants were less motivated. The accountability derived from other people knowing about an attempt to eat healthily also facilitated ongoing success. Further, it was agreed that accountability was most beneficial when a change in eating behaviour had occurred, as the new behaviour had not yet become routine. Further, the actual food choices that friends made influenced participants’ own choices either positively or negatively, such that participants felt compelled to conform to their friends’ food choices despite whether these choices were healthy or unhealthy.
Table 4.2
Representative Quotes for Theme 1: Healthy Eating Enablers and Barriers, with Focus Group Indicated

<table>
<thead>
<tr>
<th>Self-Regulation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“Mental power, definitely”</td>
<td>2</td>
</tr>
<tr>
<td>“You have to be really committed”</td>
<td>2</td>
</tr>
<tr>
<td>“Sticking to your goals. So if you see chocolate you just think; well, not having this is good for me in the long-term”</td>
<td>3</td>
</tr>
<tr>
<td>“It benefits you in the long run but it takes so long. So, you have to be willing to wait”</td>
<td>4</td>
</tr>
<tr>
<td>“Yeah, if it’s not immediate a lot of the time people are like: ‘oh screw it’”</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Success as facilitator or inhibitor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“By seeing results you feel more motivated to keep going but I think someone who wasn’t seeing immediate results, or results after a while, may be a bit discouraged to keep on going and think: ‘what’s the point?’”</td>
<td>2</td>
</tr>
<tr>
<td>“Yeah, that happens to everyone, I guess you just have to keep going or, like, be realistic about it [healthy eating]”</td>
<td>2</td>
</tr>
<tr>
<td>“On the other hand some people see results and think they’re doing well so they say: ‘Oh, I can have some chocolate’”</td>
<td>4</td>
</tr>
<tr>
<td>“People eating healthily for a while start to feel good but then they start to think they can indulge more and they’re stuck in this cycle”</td>
<td>6</td>
</tr>
<tr>
<td>“I do tend to think like that but I just keep reminding myself how good I’d feel if I kept at it [eating healthily]”</td>
<td>6</td>
</tr>
</tbody>
</table>

| Cognitive framing                                                              |   |
“It [healthy eating] should be a lifestyle”

“I think it’s [healthy eating is] a mindset that they need to keep in their minds and integrate it into their lifestyle not just during the period of time of their diet”

“Restriction”

“Deprivation”

“Boring”

“Starvation”

“...diets don’t work because they are like a temporary thing. You need to actually make a change- it [healthy eating] is something that you are now doing forever”

Peers as facilitators or inhibitors

“When you’re by yourself you’re the person in control and that’s harder... having someone push you is easier”

“I had a friend doing it with me and we were eating really healthily... but that’s why I failed because she stopped and I got discouraged”

“It’s not just the support that helps but the fact that you don’t want to look bad, like ashamed if you fail”

“You get more conscious, like my friend ate salads every day and I can’t really eat Burger King when she does that”

“You change your mind because you think people will judge you if you have a salad”

Coping with environment barriers

Availability of high-calorie foods. It was agreed that the environment provides multiple sources of inexpensive, high-calorie foods, which results in overeating and contributes to poor dietary choices. See Table 4.3 for representative quotes. Participants commented on how the availability of food encourages individuals to eat regardless of
whether they are hungry or not. However, participants believed that to some extent, this was a misinterpretation. Particularly, the notion that fast food is convenient and inexpensive was challenged. Participants discussed how people often choose fast foods as they believe they do not have enough time to prepare healthy meals, when in actuality preparing healthy meals need not be time consuming.

*Cues to action.* External factors such as advertisements and internal factors such as sensory and biological cues were seen as influencers of eating behaviour. While participants described their awareness of these cues, they described being less responsive and better able to resist the temptations stimulated by these cues in comparison to their peers. Yet, it was noted that it was not always possible to ignore external cues, particularly when participants had consumed alcohol, were stressed or bored. In order to combat the influence of such cues, participants physically altered their environments. For example, during a lunch break rather than exposing themselves to unhealthy options, they would walk to locations that offered healthy options. Additionally, they would make unhealthy food less accessible by removing tempting items from their pantry or fridge.
### Table 4.3

*Representative Quotes for Theme 2: Coping with Environmental Barriers, with Focus Group Indicated*

<table>
<thead>
<tr>
<th>Availability of high-calorie foods</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“There’s just such a high availability of bad food”</td>
<td>3</td>
</tr>
<tr>
<td>“It’s so easy to walk into McDonalds or buy a bag a chips”</td>
<td>3</td>
</tr>
<tr>
<td>“Yeah if the opportunity is there people are like okay [I’ll eat it] when really they should be questioning whether they’re actually hungry or not”</td>
<td>4</td>
</tr>
<tr>
<td>“And the idea of convenience of fast food, like that mindset that it’s quick and easy and it will fill you up… it’s like the complete opposite, because once you have it you’re never satisfied, it digests quickly and you’re looking for something else to eat”</td>
<td>3</td>
</tr>
<tr>
<td>“A lot of people think it’s too hard to eat healthy, like: ‘Aww, it’s too expensive’”</td>
<td></td>
</tr>
<tr>
<td>“It’s not always more expensive”</td>
<td>5</td>
</tr>
<tr>
<td>“I definitely feel it’s cheaper”</td>
<td>5</td>
</tr>
<tr>
<td>“People think there’s not enough time but they’ve probably never even tried. I make my lunch every day for Uni, it really doesn’t take long”</td>
<td>7</td>
</tr>
<tr>
<td>“Yeah I guess it is a bit of an excuse”</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cues to action</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“I guess advertisements really affect people, like if they see a picture of some new or delicious food they want to try it”</td>
<td>5</td>
</tr>
<tr>
<td>“…it’s the smell, like if you pass a bakery and it’s hard to stop thinking about it”</td>
<td>7</td>
</tr>
<tr>
<td>“Stuff like that use to make me eat more but now when I get full I just stop. Whatever I want to eat, I eat, but when I’m full I stop”</td>
<td>1</td>
</tr>
<tr>
<td>“If I have lack of sleep I really want to eat something”</td>
<td>1</td>
</tr>
<tr>
<td>“If you’ve been out and it’s late at night drinking then yes, it’s harder to control”</td>
<td>3</td>
</tr>
<tr>
<td>“You eat more when you’re studying, bored eating or procrastination”</td>
<td>3</td>
</tr>
</tbody>
</table>
“I always walk away and get something I know is healthy” 1
“Yes or prepare my own food” 1
“I don’t have easily accessible unhealthy stuff at home” 4
“Just having healthy foods available in your fridge” 5

Nature of self-regulation

Limited versus non-limited resource. While participants credited their success to their ability to self-regulate, it was consistently noted that this ability was a limited resource where repeated exertion led to unhealthy eating. See Table 4.4 for representative quotes. This reflects previous comments, which suggested that at times participants were more susceptible to environmental cues. However, in order to combat the limited nature of self-regulation participants exercised self-regulation in moderation and allowed a few occasions of unhealthy eating. Additionally, participants noted that with multiple successful healthy eating attempts, the process of exerting self-regulation became easier.

Carry-over effects. Participants found that exerting self-regulation in one area of life carried over to successful regulation in another area of life, such as exercise or studying. However, some individuals described that when they consistently denied themselves snack foods they experienced poorer self-regulation in another area, such as binge drinking.

Planning and monitoring. Participants described specific abilities that they regarded as responsible for their success; including planning. It was noted that the ability to plan allowed these individuals to better navigate their environment, as unhealthy options did not distract them from their healthy eating goal. Further, planning enabled participants to eat regularly, which offset the chance of engaging in unhealthy eating. Participants also described engaging in self-monitoring, whereby they were consistently aware of what they were eating rather than engaging in mindless snacking or overindulgence.
### Limited versus non-limited resource

<table>
<thead>
<tr>
<th>Quote</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>“If you deprive yourself from something for long enough, you want it”</td>
<td>7</td>
</tr>
<tr>
<td>“I don’t think it <em>sustained self-regulation</em> is possible... it just depends like how extreme the restrictions are”</td>
<td>5</td>
</tr>
<tr>
<td>“It’s better to only withhold to a limit. Maybe like over a week, <em>and</em> have a snack”</td>
<td>6</td>
</tr>
<tr>
<td>“It’s <em>moderation is</em> definitely easier to maintain than an overall restriction, you wouldn’t be able to keep that up for very long”</td>
<td>6</td>
</tr>
<tr>
<td>“I don’t think anyone can maintain it <em>self-regulation</em> long-term”</td>
<td>2</td>
</tr>
<tr>
<td>“It’s <em>self-regulation is</em> not something you can have forever”</td>
<td>1</td>
</tr>
<tr>
<td>“Just practicing saying ‘no’. If someone offered me something I’d always say: ‘yeah’, but I found when I kept saying: ‘no, I’m okay’, it got easier”</td>
<td>5</td>
</tr>
<tr>
<td>“I think… watching what you put in your mouth, it does help to an extent, like if you don’t eat chocolate for a week, you’ll find that you get better”</td>
<td>5</td>
</tr>
</tbody>
</table>

### Carry-over effects

<table>
<thead>
<tr>
<th>Quote</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Yeah it helps with everything, you’ll find that if you’re able to stick to an exercise plan you’ll be able to study better and all kinds of things”</td>
<td>3</td>
</tr>
<tr>
<td>“Completely matches what’s going on in the rest of my life, so if I’m having a crap time, I’ll probably eat whatever I want”</td>
<td>4</td>
</tr>
<tr>
<td>“… if you stop eating sweets, you substitute it with something else that’s bad, like drinking [alcohol]”</td>
<td>5</td>
</tr>
</tbody>
</table>

### Planning and monitoring

<table>
<thead>
<tr>
<th>Quote</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>“I set it all out for myself- what I’m eating and when”</td>
<td>4</td>
</tr>
<tr>
<td>“So yeah, I’m pretty good at planning, I guess”</td>
<td>3</td>
</tr>
<tr>
<td>“Like having a plan really helps, so not like; you eat whatever you want, but know what you’re doing”</td>
<td>4</td>
</tr>
</tbody>
</table>
good things you can eat and where they’re available”
“I would eat regularly; I would eat at the same time every day” 7
“I do make sure I’m aware of what I’m eating, make sure it’s not mindless” 4
“I always pull myself up like; ‘No you can’t eat that.’ I’m always monitoring, I guess it’s like a constant thing” 7

**Habit**

*Increasing automaticity.* Participants also described how after a period of successfully maintaining their behaviour, this process, and healthy eating itself, had become somewhat automatic. See Table 4.5 for representative quotes. It was suggested that developing healthy habits would be key in helping others to maintain healthy eating behaviour. Participants described their behaviour as a transition from being initially intention-based, and under cognitive control, to a less effortful process. Once behaviour had become habitual, external cues seemed to have less of an influence.

*Breaking routine.* However, when routine was broken, for example due to a social event, participants noted that they were likely to eat unhealthily and consequently experience some difficulty recruiting self-regulatory resources in order to resume their previous healthy eating behaviour. Others noted that planning was an important self-regulatory technique to utilise in these situations.
Table 4.5

Representative Quotes for Theme 4: Habit, with Focus Group Indicated

<table>
<thead>
<tr>
<th>Increasing automaticity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“I don’t think it’s a conscious thing for me anymore; that’s just how it happened for so long and it’s become routine”</td>
<td>6</td>
</tr>
<tr>
<td>“Sometimes you get into the routine and eating healthy just keeps kind of going, you don’t think about it”</td>
<td>5</td>
</tr>
<tr>
<td>“Maybe it needs to be a more subconscious thing, because people are very aware of their diets, but it just comes naturally to me”</td>
<td>7</td>
</tr>
<tr>
<td>“You contemplate and you think about it, but yeah, as soon as you get it over and done with its easier from there. It’s like you have to force yourself to do that”</td>
<td>5</td>
</tr>
<tr>
<td>“I guess getting over the initial hump of watching what you’re eating, and once you’ve gotten use it, you don’t tend to be affected by cravings so much”</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Breaking routine</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“It’s sometimes difficult on the weekend when you’re doing different things and it’s hard to keep in routine”</td>
<td>3</td>
</tr>
<tr>
<td>“I guess that’s where planning comes in”</td>
<td>3</td>
</tr>
</tbody>
</table>

Discussion

This is the first study to investigate the factors that influence the maintenance of healthy eating behaviour within a normal-weight population of young adults, and to explore their perceptions regarding how self-regulation influences healthy eating behaviour. The primary themes that emerged indicated that healthy eaters have developed numerous strategies to cope with barriers to healthy eating, including engaging in numerous self-regulatory techniques in order to lessen the negative impact of environmental triggers.
Additionally, participants described the nature of self-regulation and how continued self-regulation enables the development of healthy habits.

Overwhelmingly, participants cited ‘willpower’, and the ability to focus on long-term goals, as determinants of successful healthy eating behaviour. Interpreting these results through the reflective-impulsive model would suggest that the behaviour of successful healthy eaters is primarily directed by the reflective system and that the strength of this system is enhanced by the ability to self-regulate (Hofmann, Friese, & Strack, 2009).

Specifically, it appeared that this sample was able to focus on the long-term benefits of engaging in healthy eating behaviours while ignoring the immediate gratification gained from engaging in unhealthy eating behaviours. From descriptions such as those provided by participants in this sample, it appears that successful healthy eaters are able to delay gratification, or focus on the future consequences of their actions. Both of which are elements of self-regulation that have been found to play a role in the execution of many health enhancing behaviours (Daugherty & Brase, 2010).

**Exerting self-regulation to overcoming barriers to healthy eating behaviour**

Participants discussed numerous difficulties associated with healthy eating behaviour, but importantly, they also described how self-regulation was used to overcome these difficulties and assist in the maintenance of healthy eating behaviour. Firstly, participants discussed how a ‘diet’ is inherently temporary and ultimately leads to failure. This reflects previous literature which has found that dieting or ‘restrained eating’ is usually unsuccessful: strict control of food intake usually leads to a cycle of restriction and over-indulgence (Amigo & Fernández, 2007; Hawks, Madanat, & Christley, 2008). According to the goal-conflict model of restrained eating (Papies, Stroebe, & Aarts, 2008), this behaviour is due to a conflict between the goal to diet, and the goal to eat for enjoyment. Research on restrained eating has found that restrained eaters experience heightened reactivity to food (Brunstrom,
Yates, & Witcomb, 2004), have positive attitudes to food regardless of its palatability (Papies, Stroebe, & Aarts, 2009), and have lower response inhibition (Nederkoorn et al., 2010). This is reflected in behavioural and health outcomes where restrained eaters have been shown to consume more food than non-dieters in laboratory settings (Martin et al., 2005), and gain more weight in the long-term (Mann et al., 2007). This sample differed in that participants made dietary choices with the mindset of fulfilling a healthy lifestyle, inherent in which is the goal of maintenance. Framing in this way may establish an intention to maintain this behaviour, and if plans are made to carry out this intention or if self-regulatory capacity is strong, temptations should be easier to overcome (Gollwitzer, 1999).

Within this sample, participants described the effect of experiencing healthy eating success as twofold. Participants highlighted the importance of setting and reaching realistic goals, as this increased the salience and achievability of long-term healthy eating behaviour, and encouraged continued pursuit of healthy eating goals. This reflects findings that implicate the role of perceived behavioural control and self-efficacy in the execution of health behaviours, where the belief that a goal or behaviour is achievable will facilitate the execution of that behaviour (Conner et al., 2002). Participants also discussed how experiencing success might occasionally result in setbacks due to a self-licensing effect. Self-licensing refers to the phenomenon where individuals perceive that they have exerted self-regulation, and as a result, feel that gratification or indulgence is now justified. Research examining the relationship between self-licensing and food consumption has found that a self-licensing cue leads to an increase in unhealthy eating behaviour. Specifically, Witt Huberts, Evers, and De Ridder (2012) demonstrated that participants, who were led to believe that they had completed two tasks, consumed on average 26 grams more snacks than participants who actually performed the same tasks but thought they had only completed a single task. These findings elucidate the nature of self-regulation suggesting that a failure to
self-regulate may be due to a shift in motivation away from restricting and toward gratification (Inzlicht & Schmeichel, 2012).

**Exerting self-regulation to cope with external influences**

The influence of the external environment on eating behaviour was also discussed, wherein participants noted that the abundance of readily available unhealthy foods, and cues such as advertisements to consume unhealthy foods, trigger unhealthy eating behaviour. This reflects research which suggests that the salience of food can initiate unplanned consumption, or increase consumption in general (Remick, Polivy, & Pliner, 2009). This supports recent conceptualisations of Western societies as ‘food-rich’ environments wherein the abundance of cues and opportunities to consume unhealthy foods are seen as responsible for overconsumption and the rising rate of obesity (de Ridder, 2012; Wansink, 2004). In addition to food-related cues in the environment, friends and peers also functioned as cues to action such that the eating behaviour of others exerted a great influence on participants’ eating choices. For example, if a peer was eating healthily, participants were also more likely to experience success with their healthy eating goal and vice versa. This reflects a large body of research which suggests that, depending upon certain circumstances, social influences either facilitate or inhibit food consumption (for a review, see: Herman, Roth, & Polivy, 2003).

While participants in this sample noted the effect of social and environmental factors, they also discussed strategies that they either consciously or automatically engaged in, which enabled them to cope with such influences. For example, some participants manipulated the availability of potential triggers to unhealthy eating by removing tempting items from their homes or seeking out particular areas where they knew healthy food was available. Previous research has found that if the salience of these cues is reduced, their influence on consumption is also reduced (Coelho, Jansen, Roefs, & Nederkoorn, 2009). The removal of cues in the environment can be thought of as a self-regulatory strategy in which individuals...
who are aware that they have low in situ self-regulatory ability exert self-regulation prior to the tempting situation in order to increase the likelihood of goal attainment. The current results suggest that those who maintain healthy eating behaviours may do so as a result of self-regulatory strategies that reduce the salience of cues in the environment. Alternatively, some participants challenged the notion that the food-rich environment was influential in directing eating behaviour, suggesting that if sufficient motivation to eat healthily was present, it was not difficult to find healthy and affordable options. Previous research has shown that exposing individuals to a healthy eating goal outweighs the influence of the cue to eat unhealthily (Papies & Hamstra, 2010).

Generally, research has demonstrated that the influence of cues to action on eating behaviour is greatly determined by self-regulatory ability. In a recent study by Hall, Lowe, and Vincent (2013), participants were given instructions that either facilitated or inhibited consumption, or were given no instructions at all. Within the facilitation condition, inhibitory control strength predicted the amount of food consumed; however, in the other conditions, inhibitory control was not related to consumption. These findings suggest that inhibitory control is necessary to regulate behaviour within environments that cue unhealthy eating. Indeed, participants in the current sample seemed to be able to inhibit impulsive reactions, driven by cues to action, suggesting that their inhibitory control capacity was strong. These results highlight the importance of this facet of executive function in the regulation of eating behaviour.

The results of the current study suggest that healthy eaters were able to maintain their healthy eating goal even when faced with cues to action or other challenges. As discussed in the previous chapter, the ability to maintain and update goal-relevant information greatly influences the execution of health enhancing behaviours. Specifically, research has shown that updating capacity interacts with the strength of goals to predict eating behaviour. For
example, Hofmann, Gschwendner, et al. (2008) measured the strength of both updating capacity, and the goal to forgo sweets, and found that individual differences in goal strength only related to consumption of sweets when updating capacity was strong. Individuals with a low updating capacity were unable to carry out their goals even if these goals were strong. It was suggested that updating capacity is necessary to facilitate action in accordance with goal-directed behaviour. Superior updating capacity may explain why participants in this sample were able to maintain focus on their long-term goals and engage in healthy eating behaviour.

**Nature of self-regulation**

Research has suggested that the manner in which individuals conceptualise willpower impacts upon the ability to exert self-regulation, such that conceptualising willpower as a non-limited resource protects against depletion effects (Job et al., 2010). Specifically, Job et al. (2010) manipulated participants’ ideas concerning the nature of willpower by presenting participants with a questionnaire that either fostered the belief that willpower is a limited resource or a non-limited resource. Results demonstrated that depletion was only present within those who viewed self-regulation as limited. This result was qualified by Vohs, Baumeister, and Schmeichel (2012) who found that the interaction between conceptualisations of willpower and depletion was only present at low levels of depletion, suggesting that when individuals are more depleted, conceptualisations of their ability to self-regulate do not influence future self-regulatory attempts. Within the current sample, participants specified that self-regulation was limited by the appropriateness of an individual’s health goals and self-regulatory effort. For example, attempting to regulate behaviour to reach unrealistic goals, or constantly regulating behaviour too strictly, will ultimately lead to self-regulatory failure. These results complement the findings of Vohs et al. (2012) suggesting that while conceptualising willpower as a non-limited resource may
counter mild levels of depletion, when greater amounts of self-regulation are exerted 
depletion will ensue regardless of beliefs.

Carry-over effects described by the current sample reflect predictions of the strength 
model of self-regulation (Baumeister, Vohs, et al., 2007). Some participants described 
experiencing an inability to exert self-regulation in other areas after regulating their eating 
behaviour, reflecting a depletion effect (Hagger et al., 2010). However, others also 
experienced the generalisation of self-regulatory success, whereby carrying out healthy eating 
goals resulted in goal attainment in other domains. It has been found that exercising self-
regulation in one area leads to better self-regulation in other areas (Oaten & Cheng, 2006b; 
Oaten & Cheng, 2007). Oaten and Cheng (2006b) demonstrated that adhering to an exercise 
program for two months improved elements of self-regulation, which transferred to 
improvements in a variety of health behaviours including healthy eating behaviour. Thus, it is 
likely that while individuals become exhausted in the short-term, after a period of recovery 
and repeated self-regulatory successes, self-regulation is strengthened and adherence to 
health behaviours is maintained.

In addition, participants described how this process of exerting self-regulation and 
maintaining healthy eating behaviour became easier with time. As self-regulation improved, 
the need to consciously engage this resource declined, and exerting self-regulation, and thus 
healthy eating itself, came to reflect habitual processes. Lally, Wardle, and Gardner (2011) 
conducted a qualitative analysis of habit formation within a sample of participants who were 
enrolled in a weight loss intervention and found that in the early stages of the intervention, 
weight loss techniques were cognitively effortful; however, the amount of effort required 
progressively declined until minimal forethought was necessary to engage in weight loss 
strategies. Research has suggested that habits are formed when a specific behaviour is 
performed frequently and consistently in the same situation for the same purpose (Lally, van
Jaarsveld, Potts, & Wardle, 2010; Verplanken & Orbell, 2003). It is likely that the stable goal to eat healthily, and the repeated enactment of self-regulation techniques to achieve this goal, facilitated habit formation.

**Implications**

The present results have several implications for both theories of self-regulation and explanations of the role of self-regulation in eating behaviour. Firstly, while numerous self-regulatory strategies were discussed, it appeared that inhibitory control processes were underlying many of these strategies. Particularly, individuals appeared to employ inhibitory control to counter disruptive cues to action in the environment. Secondly, the frequent discussion regarding the ability to maintain healthy eating goals when faced with challenges, suggests that updating capacity influences healthy eating behaviour. Thirdly, there were only a few instances where participants described examples of self-regulation strategies that reflected shifting ability. As discussed in Chapter 3, research has primarily shown that shifting relates to the eating behaviour of underweight or obese individuals. Therefore, shifting may not exert a great influence on the eating behaviour of normal-weight individuals.

The results also support a dual-systems approach to healthy eating. Specifically, the reflective-impulsive model would suggest that the eating behaviour of these individuals is driven by the reflective system, which has outweighed the influence of the impulsive system due to superior self-regulatory capacity (Strack & Deutsch, 2004). Additionally, many of the self-regulatory experiences described by participants also lend support to the strength model of self-regulation (Baumeister, Vohs, et al., 2007). Namely, participants described experiences regarding depletion and the strengthening of self-regulatory capacity. Participants also described motivational factors that influenced depletion, such as self-licensing, and the conceptualisation of willpower. Recently, focus has been placed on determining the precise mechanisms underlying the depletion effect. The current results lend
support to the process model of depletion put forward by Inzlicht and Schmeichel (2012) in which it is suggested that depletion may be the result of a shift in motivation and/or attention away from self-regulatory cues and towards gratification.

Strengths and limitations

This study represents one of the first to qualitatively examine how healthy eaters successfully regulate their eating behaviour. Additionally, limited previous research has taken a qualitative approach to examining how the ability to self-regulate is perceived by individuals. The semi-structured interview schedule allowed participants to express and discuss their perceptions openly and at length. However, there are some limitations which must be considered when interpreting these results. As several of the participants described behaviours similar to that of restrained eaters, the current study may have benefited from the inclusion of a measure of dietary restraint in order to determine the level of restrained eating within this sample. However, the majority of participants indicated that restricting their intake did not lead to successful maintenance of healthy eating. Therefore, while some of the participants may have been classed as restrained eaters in the past, it is unlikely that these participants remained restrained eaters. Additionally, the majority of this sample was female, and therefore the generalisability of these findings may be compromised. Specifically, while male participants agreed with female participants on most themes, such as environmental influences, fewer males described experiences with dieting. Finally, participants primarily discussed self-regulation regarding the avoidance of unhealthy foods, rather than the consumption of healthy foods, such as fruit and vegetables. As such, it is difficult to determine whether the same self-regulatory strategies are employed when an individual is attempting to increase the performance of a health enhancing behaviour.
Conclusions

These findings reveal the processes that healthy eaters see as influential in the regulation of their eating behaviour. Healthy eaters provided insight into the nature of self-regulation and the specific strategies that they engage in to assist in the regulation of eating behaviour. Given that many young adults do not adhere to healthy eating guidelines, and current interventions aimed at improving eating behaviour are unsuccessful, these results in which factors that enable healthy eating behaviour are specifically implicated, increase our understanding of eating behaviour and may offer useful targets for interventions designed to improve eating behaviour.
Chapter 5 - Prediction of eating behaviour using executive function constructs

The primary themes that emerged from Chapter 4 indicated that healthy eaters employ self-regulatory strategies to overcome barriers to healthy eating. Specifically, healthy eaters described the ability to resist the influence of cues to eat unhealthy in the environment, suggesting that inhibitory control capacity may be influential in resisting triggers to eat unhealthily. Additionally, healthy eaters appeared to be able to maintain their healthy eating goal even when faced with challenges or cues to eat unhealthily, suggesting that updating capacity may play a role in the execution of healthy eating behaviour. These qualitative results suggest that particular facets of executive function may be important for successful implementation of healthy eating goals, and that individual differences in updating and inhibitory control may account for variance in healthy eating behaviour. However, it is not known whether these elements of executive function are differentially related to particular kinds of healthy eating behaviour, namely, whether inhibitory control and updating capacity are differentially related to saturated fat intake and fruit and vegetable consumption. The results of a study in which the aim was to determine the influence of particular facets of executive function on specific eating behaviours are reported in this chapter. Determining whether elements of executive function differentially relate to eating behaviours may be crucial to the development of a better understanding of eating behaviour and to the design of successful healthy eating interventions.

Executive function and unhealthy eating

As discussed in Chapter 3, inhibitory control has been linked to eating behaviour, where deficits in performance on measures such as the Stroop (Allan et al., 2010), GNG (Hall et al., 2008), and SST (Hofmann, Friese, & Roefs, 2009; Nederkoorn et al., 2010), are
associated with poorer eating behaviour and weight outcomes. Generally, findings from this research demonstrate that the behaviour of individuals with superior inhibitory control is driven by the reflective system, lending support to a dual-systems approach to explaining the role of self-regulation in eating behaviour. Additionally, neuroimaging research has shed light on the relationship between inhibitory control and eating behaviour. Hendrick et al. (2011) demonstrated that normal-weight women, in comparison to obese women, showed greater activation in brain regions associated with saliency processing on stop trials, compared to go trials, during performance of the SST, suggesting that normal-weight individuals may attend more to cues to inhibit undesired behaviour.

Similarly, updating capacity has been shown to relate to eating behaviour and weight outcomes, such that obese individuals tend to perform poorly on measures such as the n-back (Hege et al., 2013; Stingl et al., 2012). Higgs et al. (2012) demonstrated that when normal-weight participants were required to hold food cues in working memory, these individuals showed facilitated detection of food cues. It was suggested that deficits in updating capacity result in increased attention to food cues, which interrupts the encoding of information related to healthy eating goals. Similarly, Shaw and Tiggemann (2004) demonstrated that a specific working memory impairment was present in those who were preoccupied with thoughts of food. Finally, dual-systems approaches have demonstrated that, like inhibitory control, updating capacity is beneficial to the execution of healthy eating goals (Hofmann, Friese, & Roefs, 2009; Hofmann, Gschwendner, et al., 2008). Specifically, research has suggested that having a goal to eat healthily may only be beneficial when an individual has sufficient ability to maintain and update this goal (Hofmann, Gschwendner, et al., 2008). Indeed, Allan et al. (2013) demonstrated that plans to avoid snacking behaviour were only predictive of actual snacking behaviour amongst skilled planners, suggesting that reflective processes may only direct behaviour when self-regulatory capacity is sufficient.
Executive function and healthy eating

The majority of research examining the relationship between executive function and eating behaviour has focused on unhealthy eating behaviour, finding that poorer executive function is associated with increased consumption of unhealthy foods. The relationship between executive function and the consumption of healthy foods, such as fruits and vegetables, is less clear. In one study, inhibitory control was found to moderate the relationship between intention and behaviour such that intention was more likely to lead to fruit and vegetable consumption among those with greater inhibitory control (Hall et al., 2008). However, when using the same measure of inhibitory control and a similar measure of behaviour in a later study, Hall (2012) failed to demonstrate a comparable relationship with non-fatty food consumption. Several other researchers have also struggled to replicate this effect (Allan et al., 2011; Collins & Mullan, 2011), suggesting that inhibitory control may not play a role in the consumption of healthy foods.

In terms of updating capacity, evidence supports a link between processes related to this capacity and fruit and vegetable consumption. For example, Kang et al. (2005) found that total vegetable intake was associated with less cognitive decline in ageing participants, as measured by a memory test battery. Péneau et al. (2011) also found that higher fruit intake was related to better verbal memory, while Sabia et al. (2009) found that eating less than two serves of fruit and vegetables per day was associated with poorer executive function and memory. Additionally, Kesse-Guyot et al. (2011) found that better adherence to nutritional recommendations was significantly associated with better verbal memory. These studies appear to demonstrate a link between consuming healthy foods and reduced cognitive decline is later life. Given that the relationship between executive function and eating behaviour is likely to be bidirectional (Francis & Stevenson, 2013) it is worthwhile examining whether
updating capacity contributes to the prediction of fruit and vegetable consumption within a young adult sample.

**Avoiding consumption of unhealthy foods versus initiating consumption of healthy foods**

From the above literature, it appears that the predictive utility of executive function constructs differs according to the nature of the behaviour in question. For example, inhibitory control appears to be strongly related to unhealthy food consumption, but not the consumption of healthy foods. These behaviours differ in that avoiding foods high in saturated fat requires the suppression of goal-irrelevant responses, whereas consuming fruit and vegetables involves initiating goal-relevant responses. Previous research has established that different types of self-control can distinguish between conceptually distinct behaviours (de Boer, van Hooft, & Bakker, 2011; de Ridder, de Boer, Lugtig, Bakker, & van Hooft, 2011). Through a series of confirmatory factor analyses it was demonstrated that the Tangney et al. (2004) self-control scale consisted of two factors: inhibitory self-control and initiatory self-control. These factors were then used to predict numerous health behaviours. It was found that behaviours which required stopping a response, such as alcohol consumption and cigarette smoking, were predicted by inhibitory self-control, while behaviours that required starting a response, such as studying or exercising, were predicted by initiatory self-control (de Ridder et al., 2011). Therefore, it is plausible that tasks that index inhibitory control will only be related to the execution of goals concerning the avoidance of unhealthy food consumption, rather than goals related to the initiation of healthy food consumption. Conversely, updating capacity may be more relevant than inhibitory control to behaviours such as fruit and vegetable consumption, which require goal-relevant information to be updated and maintained in order to initiate a response.
Eating style

Previous research has demonstrated that particular eating styles impact upon eating behaviour. For example, as described in Chapter 4, dietary restraint has been shown to influence BMI and eating behaviour, such that those who report a greater concern for dieting and weight control are more impulsive and have greater difficulty executing their eating behaviour goals (Jansen et al., 2009). Additionally, results from Chapter 4 and previous research have indicated that the tendency to eat in response to external cues (Brignell, Griffiths, Bradley, & Mogg, 2009; van Strien, Peter Herman, & Anschutz, 2012), and emotional states (van Strien et al., 2013), influences eating behaviour and predicts food consumption. Therefore, it was deemed important to control for these eating styles and examine the role of executive function in eating behaviour over and above such influences.

Aims and hypotheses

The aim of this study was to determine whether individual differences in two categories of executive function could predict two eating behaviours: saturated fat intake and fruit and vegetable consumption, amongst participants with healthy eating intentions. Individuals with stated intentions to eat healthily were recruited to reduce variance attributable to individual differences in motivation. It was hypothesised that inhibitory control would predict saturated fat intake, such that those with a superior inhibitory control capacity would consume less saturated fat. It was also expected that those with a superior updating capacity would also consume less saturated fat. It was hypothesised that updating would predict fruit and vegetable consumption, such that those with a superior updating capacity would consume more fruit and vegetables. However, inhibitory control was not expected to play a role in fruit and vegetable consumption. Based on previous research, which showed that eating behaviour is also influenced by factors such as sex, BMI, and eating style (Jansen et al., 2009; Jasinska et al., 2012; van Strien et al., 2012), these variables were controlled for.
It was expected that the hypothesised relationships between inhibitory control, updating, and eating behaviour would persist when controlling for sex, BMI, and eating style.

**Method**

**Participants**

One hundred and fifteen normal-to-overweight undergraduate students from a variety of disciplines (mean age: 19.79 years, \(SD = 1.95\), 83 females) were recruited to participate in exchange for course credit. Inclusion criteria included holding an intention to eat healthier, not colour blind, fluent in English, having regular access to the internet, and having no current or prior diagnosis of an eating disorder. All participants provided informed consent before taking part in the study, which was approved by the university Human Research and Ethics Committee. See Appendix A for ethics approval related to this study.

**Materials and measures**

**BMI.** BMI was calculated from participants’ self-reported height and current weight. Participants were also asked to indicate the presence of a current or lifetime eating disorder diagnosis in order to confirm that the exclusion criteria were met.

**Eating style.** Eating styles were measured using the Dutch eating behaviour questionnaire (van Strien, Frijters, Bergers, & Defares, 1986), which consists of 10 items assessing restrained eating (i.e., the tendency to restrict food intake due to a concern for weight), 10 items assessing external eating (i.e., the tendency to eat in response to external food-related cues), and 13 items assessing emotional eating (i.e., the tendency to eat in response to negative emotions such as anxiety and depression). See Appendix C for items in the Dutch eating behaviour questionnaire. Responses ranged from: never (1) to very often (5), and subscale scores reflected the weighted average of relevant items. These subscales have been shown to have high internal consistency, high predictive validity for food consumption,
and high convergent and discriminative validity (van Strien, Frijters, Van Staveren, Defares, & Deurenberg, 1986). All subscales had good internal consistency in the present sample (restrained eating: $\alpha = 0.91$; external eating: $\alpha = 0.83$; emotional eating: $\alpha = 0.94$).

**Eating Behaviour.** The Block food screener (Block, Gillespie, Rosenbaum, & Jenson, 2000), which has been validated against the 1995 Block 100-item food frequency questionnaire, was used to measure saturated fat intake and fruit and vegetable consumption. For saturated fat intake, participants indicated how often they ate 17 meat and snack items (e.g., full-fat cheese, full-fat ice-cream, fried potatoes) on a five-point scale ranging from 0-4: never (0); once per week (1); 1-2 times per week (2); 3-4 times per week (3); 5 or more times per week (4). Scores were summed and entered into the validated formula in order to calculate daily saturated fat intake in grams. For fruit and vegetable consumption, participants indicated how often they ate seven fruit and vegetable items (e.g., fresh or canned fruit, fruit juice, any kind of vegetable) on a six-point scale ranging from 0-5: less than once per week (0); about once per week (1); 2-3 times per week (2); 4-6 times per week (3); every day (4); 2 or more times per day (5). Scores were summed and entered into the validated formula to calculate servings per day according to the pyramid definition of a serving of fruit or vegetable (US Department of Agriculture & US Department of Health and Human Services, 2010). Participants were also given descriptions of serving sizes for fruit and vegetables. See Appendix C for all items in the Block food screener, and descriptions of a serving of fruit and a serving of vegetables.

**Stroop interference task.** Inhibitory control was assessed using a computerised version of the Stroop interference task (3 blocks of 60 trials each, practice block of 20 trials). In this task, participants must press a key corresponding to the colour in which a word, or a string of letters, is printed as quickly as possible, while making as few errors as possible. Congruent trials consisted of colour words that were printed in the corresponding colour (e.g., the word
RED coloured in red). In *incongruent trials*, the colour of the colour word was different to the word itself (e.g., the word RED coloured in blue). These trials require inhibitory control as participants must name the colour of the word while inhibiting the tendency to read the word itself. *Control trials* consisted of a block of colour approximately the size of the colour words. See Figure 3.3 for a depiction of the Stroop task and trials. Stimuli were displayed until the participant responded. The response-stimulus interval was 500ms. The Stroop interference score was calculated as the difference between mean response time of correct responses on incongruent trials and mean response time of correct responses on control trials (MacLeod, 2005), where a larger score indicated poorer inhibitory control. Response times that fell three standard deviations above or below a participant’s mean reaction time per block were deemed to be outliers and were deleted (MacLeod, 2005).

*Stop-signal task.* The SST (Verbruggen, Logan, & Stevens, 2008) was included as a second measure of inhibitory control. Each trial began with a fixation cross (+) presented in the centre of the screen for 500ms. After this fixation cross, an image of a left arrow or a right arrow was presented. Participants were required to quickly categorise the content of the picture by pressing the “D” key for a left arrow, or the “K” key for a right arrow, counterbalanced across participants. On 25% of trials, an auditory tone occurred after a delay, which signified that participants should inhibit their motor response on that trial and wait for the next trial. See Figure 3.4 for a depiction of the SST. The stop-signal delay was initially set at 250ms and was adjusted dynamically according to participants’ responses using a staircase tracking procedure: when inhibition was either successful or unsuccessful the delay increased or decreased by 50ms respectively. On stop-signal trials, responses within the 1500ms timeout period were classed as inhibition errors. The task was split into four blocks: a practice block of 32 trials and three experimental blocks of 64 trials. Participants who inhibited significantly more or less than 50% of the time were removed from analysis as this
indicated they were not responding correctly to the stop-signal. Inhibitory control was assessed using the mean stop-signal reaction time, which was calculated using the subtraction method in which the mean stop-signal delay is subtracted from the raw mean reaction time for all no-signal trials (Logan, 1994; Verbruggen et al., 2008). A greater stop-signal reaction time indicated poorer inhibitory control.

Single adaptive n-back. The single adaptive n-back using visual stimuli (Jaeggi et al., 2010), was used to assess updating ability. Participants were shown a series of random yellow shapes, presented centrally on a black background for 500ms each, followed by a 2500ms inter-stimulus interval. Participants were required to respond when the current shape matched the shape presented n positions back in the series. See Figure 3.5 for a depiction of the n-back. Participants began on the 1-back level and the level of n was adjusted after each block according to performance: if less than 3 errors were made n increased by 1, while if more than 5 errors were made n decreased by 1 but never decreased lower than the 1-back, if 3-5 errors were made, n stayed the same. The task consisted of 15 blocks of 24 trials. Updating ability reflected the proportion of hits minus false alarms averaged over all n-back levels, such that higher scores indicated greater updating capacity.

Automated operation span task. The OSPAN task (Turner & Engle, 1989), required participants to indicate whether a math equation (e.g., (1*2) + 1 = 4) was true or false. Following the equation, participants were presented with a letter for 800ms, which was to be recalled. The presentation of equations and letters continued until the set size had been reached for that block. The recall screen, consisting of a 4 x 3 matrix of letters, was then presented in which participants indicated the letters that had been presented to them in the correct order. See Figure 3.6 for a depiction of the OSPAN. Set sizes ranged from 3 – 7 equation-letter presentations, with three blocks of each set size, presented in random order so that participants could not predict the number of items to be recalled. If the participants took
more time to solve the math equations than their average time calculated from practice trials plus 2.5 SD, the program automatically moved on and counted that trial as an error. This was to prevent participants from rehearsing the letters when they should be solving the equations. To ensure participants were attempting to solve both the math equations and remember the letters, an 85% accuracy criterion was imposed for math equations. Updating was assessed by OSPAN score, which was the sum of all perfectly recalled sets, such that if an individual correctly recalled 2 letters in a set size of 2, 4 letters in a set size of 4, and 3 letters in a set size of 5, OSPAN score would be 6 (2 + 4 + 0). A higher OSPAN score indicated greater updating ability.

Procedure

The study was conducted entirely online. Following sign-up and consent, participants received the link to a survey containing demographic variables and the Dutch eating behaviour questionnaire. They were then directed to the first two executive function tasks. The next day participants were emailed a link to the remaining tasks and finally, one week later, were emailed a link to a survey containing the eating behaviour questionnaires. The order of executive function tasks across the two-day period was counterbalanced across participants to control for the possible influence of order effects. Participants were also instructed to take a five-minute break between executive function tasks in order to avoid a depletion effect, which may have resulted in diminished performance on subsequent tasks. All executive function tasks were administered through Inquisit 3 by Millisecond Software, while the survey was administered through LimeSurvey.

Data analysis

Pearson product correlations were computed to examine the relationships between BMI, eating styles, inhibitory control, updating, saturated fat intake, and fruit and vegetable consumption. Identical hierarchical regression analyses were conducted to measure the utility
of inhibitory control (Step 3), and updating (Step 4) for predicting either saturated fat intake or fruit and vegetable consumption while controlling for BMI and sex (Step 1), and eating styles (Step 2).

**Results**

**Outliers**

The responses on the Stroop task of five participants exceeded the recommended quantity of acceptable outliers (3%; Ratcliff, 1993) and their responses were therefore removed from analysis. On average, 3.71 (2.06%) responses were removed for each participant.

**BMI**

BMI ranged from 18.52 to 33.20 kg/m$^2$ ($M= 21.96, SD = 3.10$), and 85% of the sample were within the normal BMI range.

**Correlations**

As can be seen in Table 5.1, BMI was positively correlated with restrained eating, such that those with a higher BMI tended to have a more restrained eating style. BMI was also correlated with eating behaviour, such that those with a higher BMI tended to have a higher saturated fat intake, and consume less fruit and vegetables. All three eating styles correlated with saturated fat intake, such that those who tended to have a restrained eating style ate less saturated fat, and those who tended to have an external and emotional eating style ate more saturated fat. Both measures of inhibitory control were positively correlated with saturated fat intake, such that those with poorer inhibitory control consumed more saturated fat; however, neither measure of updating was correlated with saturated fat intake. Both measures of updating were positively correlated with fruit and vegetable consumption, such that greater updating ability was related to higher consumption of fruit and vegetables.
Neither measure of inhibitory control, nor any of the eating styles, were related to fruit and vegetable consumption.
Table 5.1

Means, Standard Deviations, and Pearson’s Correlations of BMI, Eating Styles, Executive Function, and Saturated Fat Intake and Fruit and Vegetable Consumption

<table>
<thead>
<tr>
<th></th>
<th>BMI</th>
<th>RE</th>
<th>XE</th>
<th>EE</th>
<th>Stroop</th>
<th>SST</th>
<th>n-back</th>
<th>OSPAN</th>
<th>SF</th>
<th>FV</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>1</td>
<td>.191</td>
<td>-.115</td>
<td>-.049</td>
<td>.075</td>
<td>.016</td>
<td>-.053</td>
<td>-.056</td>
<td>.192</td>
<td>-.204</td>
</tr>
<tr>
<td>RE</td>
<td>1</td>
<td>-.008</td>
<td>.146</td>
<td>-.068</td>
<td>-.088</td>
<td>.063</td>
<td>-.078</td>
<td>-.259</td>
<td>.206</td>
<td>.103</td>
</tr>
<tr>
<td>XE</td>
<td>1</td>
<td></td>
<td>.554</td>
<td>.020</td>
<td>-.031</td>
<td>.075</td>
<td>-.064</td>
<td>.206</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE</td>
<td>1</td>
<td></td>
<td></td>
<td>-.054</td>
<td>-.005</td>
<td>-.120</td>
<td>.039</td>
<td>.210</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroop</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>.237</td>
<td>-.190</td>
<td>.300</td>
<td>-.014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SST</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>.052</td>
<td>.049</td>
<td>.274</td>
<td>-.029</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n-back</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.216</td>
<td>.120</td>
<td>.195</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSPAN</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.029</td>
<td>.280</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FV</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>3.102</td>
<td>.824</td>
<td>.604</td>
<td>.778</td>
<td>130.589</td>
<td>55.168</td>
<td>.944</td>
<td>15.625</td>
<td>7.001</td>
<td>2.032</td>
</tr>
</tbody>
</table>

*Note. BMI = body mass index; RE = restrained eating; XE = external eating, EE = emotional eating; SST = stop-signal task performance; OSPAN = operation span task performance; SF = saturated fat intake; FV = fruit and vegetable consumption.*

*p < 0.05; **p < 0.01.
**Saturated fat intake**

Sex and BMI accounted for 6% of the variance in saturated fat intake, although sex was the only significant predictor in this step, with males tending to eat more saturated fat (see Table 5.2). At step 2, eating styles accounted for an additional 14.2% of variance in saturated fat intake, with both restrained and emotional eating significantly predicting saturated fat intake. The unique influence of external eating was not significant. At step 3, inhibitory control accounted for an additional 11.8% of variance in saturated fat intake and both measures of inhibitory control were significant predictors of saturated fat intake. Updating did not account for a significant amount of variance in saturated fat intake. The final model accounted for 33.6% of the variance in saturated fat intake, with restrained eating, emotional eating, and inhibitory control making significant independent contributions, while sex remained a marginally significant predictor ($p = .053$).
Fruit and vegetable consumption

As can be seen in Table 5.3, sex and BMI accounted for 6.8% of the variance in fruit and vegetable consumption; however, BMI was the only significant predictor in this step, indicating that those with a higher BMI tended to eat less fruit and vegetables. Eating styles at step 2 did not account for a significant proportion of variance in fruit and vegetable consumption, and nor did inhibitory control at step 3. At step 4, updating accounted for an additional 7.6% of the variance in fruit and vegetable consumption; however, only OSPAN performance, not n-back performance, was significant. The final model accounted for 18.2% of the variance in fruit and vegetable consumption, with OSPAN performance making a significant independent contribution, while BMI remained a marginally significant predictor ($p = .058$).

Table 5.2
Hierarchical Regression Analysis for Prediction of Saturated Fat Intake

<table>
<thead>
<tr>
<th>Step</th>
<th>Predictor</th>
<th>$R^2$</th>
<th>$\Delta F$</th>
<th>df</th>
<th>$\beta$</th>
<th>Final $\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>sex</td>
<td>.060</td>
<td>3.429*</td>
<td>108</td>
<td>-.246*</td>
<td>-.191</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
<td>-.005</td>
<td>.083</td>
</tr>
<tr>
<td>2</td>
<td>RE</td>
<td>.201</td>
<td>6.214**</td>
<td>105</td>
<td>-.277**</td>
<td>-.250**</td>
</tr>
<tr>
<td></td>
<td>XE</td>
<td></td>
<td></td>
<td></td>
<td>.095</td>
<td>.066</td>
</tr>
<tr>
<td></td>
<td>EE</td>
<td></td>
<td></td>
<td></td>
<td>.241*</td>
<td>.284**</td>
</tr>
<tr>
<td>3</td>
<td>Stroop</td>
<td>.319</td>
<td>8.914**</td>
<td>103</td>
<td>.230**</td>
<td>.234**</td>
</tr>
<tr>
<td></td>
<td>SST</td>
<td></td>
<td></td>
<td></td>
<td>.211*</td>
<td>.201*</td>
</tr>
<tr>
<td>4</td>
<td>n-back</td>
<td>.336</td>
<td>1.232</td>
<td>101</td>
<td>.129</td>
<td>.129</td>
</tr>
<tr>
<td></td>
<td>OSPAN</td>
<td></td>
<td></td>
<td></td>
<td>.008</td>
<td>.008</td>
</tr>
</tbody>
</table>

*Note. BMI = body mass index; RE = restrained eating; XE = external eating, EE = emotional eating; SST = stop-signal task performance; OSPAN = operation span task performance; overall $R^2 = .336$, *$p < .05$; **$p < .01$. 

Fruit and vegetable consumption

As can be seen in Table 5.3, sex and BMI accounted for 6.8% of the variance in fruit and vegetable consumption; however, BMI was the only significant predictor in this step, indicating that those with a higher BMI tended to eat less fruit and vegetables. Eating styles at step 2 did not account for a significant proportion of variance in fruit and vegetable consumption, and nor did inhibitory control at step 3. At step 4, updating accounted for an additional 7.6% of the variance in fruit and vegetable consumption; however, only OSPAN performance, not n-back performance, was significant. The final model accounted for 18.2% of the variance in fruit and vegetable consumption, with OSPAN performance making a significant independent contribution, while BMI remained a marginally significant predictor ($p = .058$).
The aim of this study was to determine which facets of executive function were related to saturated fat intake and fruit and vegetable consumption, while controlling for demographic variables and eating styles. As hypothesised, those with a higher inhibitory control capacity consumed less saturated fat; however, contrary to expectations, updating ability was not related to saturated fat intake. Updating was related to fruit and vegetable consumption, such that those with a superior updating ability consumed more fruit and vegetables, and as expected, inhibitory control was not related to fruit and vegetable consumption.

Table 5.3

Hierarchical Regression Analysis for Prediction of Fruit and Vegetable Consumption

<table>
<thead>
<tr>
<th>Step</th>
<th>Predictor</th>
<th>R²</th>
<th>ΔF</th>
<th>df</th>
<th>β</th>
<th>Final β</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>sex</td>
<td>.068</td>
<td>3.941*</td>
<td>108</td>
<td>-.183</td>
<td>-.132</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
<td>-.272**</td>
<td>-.204</td>
</tr>
<tr>
<td>2</td>
<td>RE</td>
<td>.104</td>
<td>1.391</td>
<td>105</td>
<td>-.113</td>
<td>-.127</td>
</tr>
<tr>
<td></td>
<td>XE</td>
<td></td>
<td></td>
<td></td>
<td>-.034</td>
<td>-.030</td>
</tr>
<tr>
<td></td>
<td>EE</td>
<td></td>
<td></td>
<td></td>
<td>.189</td>
<td>.191</td>
</tr>
<tr>
<td>3</td>
<td>Stroop</td>
<td>.105</td>
<td>.105</td>
<td>103</td>
<td>.004</td>
<td>.053</td>
</tr>
<tr>
<td></td>
<td>SST</td>
<td></td>
<td></td>
<td></td>
<td>-.044</td>
<td>-.073</td>
</tr>
<tr>
<td>4</td>
<td>n-back</td>
<td>.182</td>
<td>4.712*</td>
<td>101</td>
<td>.128</td>
<td>.128</td>
</tr>
<tr>
<td></td>
<td>OSPAN</td>
<td></td>
<td></td>
<td></td>
<td>.225*</td>
<td>.225*</td>
</tr>
</tbody>
</table>

Note. BMI = body mass index; RE = restrained eating; XE = external eating, EE = emotional eating; SST = stop-signal task performance; OSPAN = operation span task performance; overall $R^2 = .182$, *$p < 0.05$; **$p < 0.01$.

Discussion

The aim of this study was to determine which facets of executive function were related to saturated fat intake and fruit and vegetable consumption, while controlling for demographic variables and eating styles. As hypothesised, those with a higher inhibitory control capacity consumed less saturated fat; however, contrary to expectations, updating ability was not related to saturated fat intake. Updating was related to fruit and vegetable consumption, such that those with a superior updating ability consumed more fruit and vegetables, and as expected, inhibitory control was not related to fruit and vegetable consumption.
**Saturated fat intake and inhibitory control**

The current results suggest that amongst people with healthy eating intentions, individual differences in inhibitory control capacity predict saturated fat intake. This is in line with dual-systems models which suggest that when conflict arises between achieving a goal and engaging in automatic tendencies that thwart goal attainment, these tendencies must be inhibited to successfully carry out goal-directed behaviour (Hofmann, Friese, et al., 2008; Strack & Deutsch, 2004). The current results are similar to Honkanen et al. (2012) who demonstrated that food-related self-control moderated the relationship between attitudes towards unhealthy snacking and behaviour, such that within those with stronger self-control, attitudes towards snacking were more likely to guide behaviour. Similarly, Hofmann, Friese, and Roefs (2009) demonstrated that within those with low inhibitory control as measured by the SST, automatic affective reactions to chocolate guided consumption. Therefore, it appears that inhibitory control is necessary in order for individuals to behave in line with their healthy eating goals.

Hofmann, Gschwendner, et al. (2008) also demonstrated the same relationship between automatic affective reactions and chocolate consumption within those who performed poorly on the OSPAN, suggesting that updating is also required to carry out goal-directed behaviour. Therefore, it was surprising that updating ability did not relate to saturated fat intake in the current study. Research suggests that updating enables individuals to resist the attentional capture of stimuli at early stages of processing (Friese, Bargas-Avila, Hofmann, & Wiers, 2010). However, strategies that assist goal-directed behaviour once attention has been captured, such as stopping a response to tempting stimuli, may be more relevant to avoiding consumption of foods high in saturated fat. Alternatively, it is possible that updating does not play a direct role in saturated fat intake, such that it is only predictive amongst those with strong implicit preferences for unhealthy foods. As such, future research
should attempt to resolve these inconsistent findings by including implicit measures of impulsive determinants of saturated fat intake, and testing both direct and indirect relationships between updating and saturated fat intake. Additionally, alternative measures of updating, particularly those which include stimuli related to the behaviour of interest, such as the food-back used by Hege et al. (2013) and Stingl et al. (2012), may further elucidate the role of updating in saturated fat intake.

**Fruit and vegetable consumption and updating**

Healthy eating involves not only avoiding foods that are high in saturated fat but also the approach behaviour of consumption of fruit and vegetables. Limited research has linked the consumption of healthy foods with measures of executive function. As expected, inhibitory control did not play a role in fruit and vegetable consumption. This is consistent with previous research that has failed to find a relationship between inhibitory control and healthy eating behaviours including fruit and vegetable consumption (Allan et al., 2011; Collins & Mullan, 2011; Hall, 2012), and breakfast consumption (Wong & Mullan, 2009). The current findings are also consistent with a series of studies by Mullan and colleagues that failed to find a relationship between inhibitory control and many health enhancing behaviours including food hygiene (Fulham & Mullan, 2011), and sun protection behaviour (Allom et al., 2013). It appears that for health enhancing behaviours, which usually require the initiation of a response, rather than inhibition of a response, inhibitory control is not necessary.

The novel finding that updating predicted fruit and vegetable consumption sheds some light on how health enhancing behaviours are successfully carried out. Updating is said to directly support active representations of self-regulatory goals and the associated means by which these goals can be attained (Kruglanski et al., 2002; Miller & Cohen, 2001). It appears that goal representation and maintenance are particularly important for health enhancing behaviours, which require the initiation, rather than inhibition, of a response. Specifically, a
superior updating ability may enable the management of attentional resources (Higgs et al., 2012), which in turn, results in individuals seeking out opportunities to eat fruit and vegetables.

*Saturated fat intake versus fruit and vegetable consumption*

These results appear to indicate that the predictive utility of executive function constructs differs according to the nature of the behaviour in question. For example, behaviours which involve stopping impulsive responses, such as avoiding the consumption of foods high in saturated fat, appear to be related to inhibitory control capacity, while behaviours that involve actively seeking out a stimulus, such as consuming the appropriate amount of fruit and vegetables, are conversely related to updating. The results are similar to previous research, which has suggested that inhibitory self-control and initiatory self-control can distinguish between conceptually distinct behaviours (de Boer et al., 2011; de Ridder et al., 2011; Kruglanski et al., 2002; Miller & Cohen, 2001). Results from the current study, which suggest that different facets of executive function predict distinct eating behaviours, lend greater support to the notion that self-regulation is multifaceted. Further, taken together, the results of the current study and that of de Ridder et al. (2011), suggest that updating may be conceptually similar to initiatory self-control and thus important in the initiation of goal-directed behaviour.

Finally, that eating styles were related to saturated fat intake but not fruit and vegetable consumption, further solidifies the difference between these two behaviours and highlights the importance of understanding not only what leads to the consumption of unhealthy foods but also to the consumption of healthy foods. Additionally, the overall variance accounted for in healthy eating behaviour was much lower than that accounted for in unhealthy eating behaviour. It appears that eating styles are more strongly predictive of unhealthy eating behaviour. The constructs of external and emotional eating, and restrained
eating reflect eating based on impulse or resisting an impulse, respectively. Therefore, it is plausible that these styles only relate to behaviours that involve stopping impulsive tendencies.

Implications

The current results have numerous applications for the improvement of eating behaviour and health outcomes in general. Firstly, the current results may add to the development of frameworks that allow for greater understanding of similarities and differences between health behaviours. For example, the classification framework put forth by McEachan, Lawton, and Conner (2010), which describes three dimensions on which health behaviours may fall and provides specific predictions about how health behaviours are executed. Understanding the characteristics of health behaviours, and how these characteristics determine the performance of health behaviours, may aid in the development of effective intervention strategies. Specifically, the current results clarified the relationship between particular facets of executive function and eating behaviours, suggesting that interventions aiming to improve these behaviours may benefit from targeting the appropriate element of executive function.

Current evidence suggests that executive function can be modified to improve outcomes such as health behaviours. For example, Houben (2011) demonstrated that participants with initially low inhibitory control who completed a modified SST, which trained the inhibition of responses to high-calorie foods, consumed less than those who were not trained to inhibit responses. In terms of updating training, much research has focused on using tasks such as the n-back to improve fluid intelligence; however, evidence suggests that training does not transfer to improvement in intelligence (for a review, see: Melby-Lervåg & Hulme, 2012; Shipstead, Redick, & Engle, 2012). Therefore, training of inhibitory control may offer a more promising avenue to improve eating behaviour. However, the size and
consistency of the effect of inhibitory control training is not known and an examination of the efficacy of such training paradigms is warranted.

**Strengths and limitations**

A strength of the current study was the examination of the relationship between executive function and both healthy and unhealthy eating behaviour, rather than focusing solely on unhealthy eating behaviour. Additionally, the inclusion of eating styles made it possible to determine the direct effect of executive function on eating behaviour once known contributors were accounted for. The study was limited in that while participants were recruited on the basis of having the intention to eat healthier, the strength of participants’ intentions was not assessed. It has been established that individual differences in motivation interact with individual differences in executive function to influence eating behaviour (Allan et al., 2011; Honkanen et al., 2012). While the relationship between executive function and the intention-behaviour gap is an important line of enquiry, exploring this phenomenon was beyond the aims of the present study.

Additionally, the current research was limited by the correlational nature of the data. From these results, it is difficult to determine whether individuals who were better able to carry out their goals did so due to superior executive function, or whether healthy eating behaviour led to improvements in executive function. For example, a recent review of cognitive function and the Western diet (i.e. high in saturated fat and refined carbohydrates), suggested that the Western diet leads to impaired brain function and also contributes to the development of neurodegenerative conditions (Francis & Stevenson, 2013). It is likely that the relationship between executive function and eating behaviour is bidirectional. As mentioned in Chapter 3, studies aiming to manipulate executive function in order to alter eating behaviour have shown that inducing a mindset of inhibition versus impulsivity results in less food consumed in a pseudo taste test (Guerrieri et al., 2009). Additionally, Smith, Hay,
Campbell, and Trollor (2011) reviewed the literature on the association between obesity and cognitive function across the lifespan and concluded that the evidence suggests that weight gain results, at least in part, from a neurological predisposition that is characterised by reduced executive function, and in turn obesity itself has a compounding negative impact on the brain and cognitive function.

Finally, undergraduate students formed the sample for the current study, limiting the generalisability of the results. It has been suggested that this demographic have more advanced cognitive test-taking skills (Foot & Sanford, 2004). Additionally, given that executive function has been suggested to relate to intelligence (Ardila, Pineda, & Rosselli, 2000), executive function scores in this sample may be higher than those in the general population. However, as individual differences in executive function were predictive of eating behaviour, it is likely that the trends observed in this research, although perhaps weaker, are reflective of that present in the general population.

Conclusions

The results of this study further our knowledge of the processes involved in healthy eating, and lend support to the distinction between different types of self-regulation that deRidder et al. (2011) put forth by dissociating two related but conceptually distinct health behaviours using several measures of executive function. Taken together these results indicate that superior executive function in one domain does not necessarily lead to the successful performance of all health behaviours. Moreover, the particular elements of executive function that are important for one type of behaviour are not necessarily related to another. Specifically, inhibitory control is important for behaviours that require the stopping of a response, such as limiting the intake of foods high in saturated fat, while updating is important for carrying out behaviours that require the initiation of a response, such as fruit and vegetable consumption.
Chapter 6 - Determining the efficacy of current executive function training interventions

In the previous chapter, it was demonstrated that inhibitory control and updating ability are involved in the execution of healthy eating behaviours. Therefore, it was suggested that interventions with the aim of improving eating behaviour, by reducing saturated fat intake or increasing fruit and vegetable consumption, might benefit from the inclusion of an executive function training paradigm. Recently, much research has been directed toward developing and implementing executive function training paradigms; however, due to inconsistent findings there is a need to review this literature in order to determine whether these intervention strategies effectively engender behaviour change. In this chapter the results of a meta-analysis examining the effect of inhibitory control training on health behaviour are reported. The scope of the analysis was extended beyond eating behaviour to include executive function training interventions that targeted other health behaviours. This was primarily because only a limited number of studies have used inhibitory control training to improve eating behaviour and it was considered essential to include all available evidence regarding the influence of training on behavioural outcomes. Concerning updating training paradigms, while numerous studies have attempted to improve this capacity, only one study has implemented updating training with the specific aim of improving health behaviour (Houben, Wiers, & Jansen, 2011). As such, the updating training literature will not be reviewed; however, a brief discussion of this literature is presented below.

Updating training

Numerous studies have attempted to improve updating capacity through training on tasks such as the $n$-back (Dahlin, Neely, Larsson, Bäckman, & Nyberg, 2008; Jaeggi,
Buschkuehl, Jonides, & Perrig, 2008; Olesen, Westerberg, & Klingberg, 2004), and the OSPAN (Bomyea & Amir, 2011; Chein & Morrison, 2010). Typically, updating training involves completing several sessions of an adaptive updating task in which the difficulty of the task is adjusted according to the participant’s performance. Improvement in updating capacity is indexed by improved performance on a related but non-trained updating task. For example, Seidler, Bernard, Buschkuehl, Jonides, and Humfleet (2010) demonstrated that 25 sessions of $n$-back training resulted in improvement in OSPAN performance. Updating training has also led to improvements in other cognitive capacities such as fluid intelligence and reasoning ability (Jaeggi et al., 2008; Olesen et al., 2004). However, it has been suggested that these results may be an artefact of methodological design (Shipstead et al., 2012; Slagter, 2012). When such studies were conducted with appropriate control conditions and suitable transfer tasks, there was limited evidence that updating training effectively improved performance on other working memory tasks and fluid intelligence measures (Chooi & Thompson, 2012; Melby-Lervåg & Hulme, 2012; Shipstead et al., 2012).

There is limited research assessing the effect of updating training on improvement in health behaviours. In one study, three adaptive updating tasks were used to train updating capacity and decrease drinking behaviour (Houben, Wiers, et al., 2011). Participants were required to complete 25 sessions of adaptive updating training and report their drinking behaviour before training, one week post-training, and one month following post-training assessment. Results indicated that those who received adaptive training reported less alcohol consumption one week after training, compared to those who received non-adaptive training, and these changes were maintained at follow-up. While these results appear promising, replication is necessary in order to reach any firm conclusions on whether updating capacity can be trained to improve health behaviours and particularly, to determine whether updating training may be beneficial to healthy eating.
**Inhibitory control training**

Inhibitory control training typically involves regular practice on a cognitive task said to tax inhibitory control, such as the GNG task (Donders, 1969) or the SST (Lappin & Eriksen, 1966). Improvement in behaviour is usually assessed using a between-participants design wherein participants who are randomly assigned to receive inhibitory control training are expected to demonstrate superior behaviour regulation compared to those assigned to an inert or alternative form of training (Houben & Jansen, 2011; Jones & Field, 2012).

Specifically, in GNG training paradigms, participants are required to respond as rapidly as possible to a neutral set of stimuli while withholding responses to a set of stimuli representing the target behaviour. Consistent pairings of the no-go response with target stimuli facilitates the retrieval of no-go-target stimuli associations and results in improved inhibition of responses to target stimuli. For example, Houben, Nederkoorn, Wiers, and Jansen (2011) used a GNG with alcohol-related stimuli in order to reduce alcohol consumption. In the training condition, no-go stimuli were consistently paired with alcohol-related stimuli, and go stimuli were consistently paired with neutral stimuli. In the control condition go stimuli were consistently paired with alcohol-related stimuli, and no-go stimuli were consistently paired with neutral stimuli. The training condition reported less alcohol consumption after training, compared to the control condition, suggesting that an association between alcohol stimuli and a no-go response had been established in the training condition and that this transferred to reductions in alcohol consumption.

In SST training paradigms, participants are instructed to categorise both target stimuli and neutral stimuli as rapidly as possible. However, on a proportion of trials the stop-signal is presented after target stimuli and participants are required to inhibit their responses. In this way, an association between target stimuli and the stop response is established. In the control condition, stop-signals are not consistently paired with a particular category of stimuli, or are
not presented at all. For example, one study aimed to improve the inhibition of responses to high-calorie foods and therefore paired high-calorie food items with a stop-signal (Houben, 2011). This was in comparison to a condition in which stop-signals were never paired with high-calorie food items. Participants who received inhibitory control training consumed significantly less high-calorie food during a pseudo taste test administered immediately after training, compared to those in the control condition. This suggests that establishing an association between unhealthy food and a stop response results in a reduction in consumption of unhealthy foods.

While numerous inhibitory control studies have been carried out with varying success, in terms of producing differences in health behaviour, few studies have attempted to ascertain the mechanism responsible for such differences. According to a dual-systems account of health behaviour, behaviour can be modified by either: changing impulsive tendencies, improving the ability to self-regulate, or by changing the reflective system (Friese, Hofmann, & Wiers, 2011). Preliminary evidence suggests that GNG training improves health behaviour by changing impulsive tendencies. For example, Houben, Havermans, Nederkoorn, and Jansen (2012) employed an implicit association task (Greenwald, McGhee, & Schwartz, 1998), and another measure of inhibitory control (the SST), and demonstrated that GNG training reduced alcohol consumption by devaluation of the alcohol-related stimuli, rather than by increased inhibitory control, suggesting that GNG training results in a decrease in the influence of impulsive processes rather than an increase in the ability to self-regulate. This is in contrast to mechanistic explanations regarding the effect of SST training on health outcomes, which suggest that SST training improves health behaviour by strengthening the ability to self-regulate. Houben (2011) found that individuals with low baseline inhibitory control ability benefited from SST training, while individuals with high baseline inhibitory control ability did not. This suggests that SST training improves behaviour by strengthening
inhibitory control; however, as no additional measure of response inhibition was included in this study, it is not known whether this assumption is accurate.

Inhibitory control training appears to result in differences in health behaviour between trained and non-trained participants; however, the size and nature of the effect is not known. Namely, the above discussion regarding differences between training paradigms, and potential mechanisms responsible for differences in health behaviour, reveals that there are a number of potential moderators that may influence the relationship between inhibitory control training and behavioural regulation.

**Potential moderators of training effect**

*GNG versus SST.* As described above, the two training paradigms differ in that in the GNG, the go response is consistently inhibited for all members of a certain category, while in the SST the ‘go’ response does not need to be inhibited for all members of a certain category, only for a certain proportion. It was suggested that the mechanisms by which these two paradigms influence health behaviour may differ, such that GNG training improves health behaviour by decreasing implicit attitudes towards the target health behaviour (Houben et al., 2012), whereas SST training may improve inhibitory control (Houben, 2011). Examining whether the effectiveness of these training paradigms differs may indicate the efficacy of particular tasks used to influence health behaviour, and the mechanism by which these tasks influence behaviour.

*Behaviour-specific versus neutral training task.* Both the GNG and the SST can be tailored to train inhibitory control in response to a group of stimuli associated with a particular behaviour. For example, if a reduction in alcohol consumption is the goal, the GNG may be tailored to include alcohol-related stimuli that are consistently associated with no-go stimuli. However, several studies have also utilised an inhibitory control task with neutral stimuli (Guerrieri et al., 2012; Verbruggen, Adams, & Chambers, 2012; Verbruggen et al.,
2013), wherein it is hypothesised that training of a general inhibitory control mechanism is sufficient to improve behaviour regulation. While it is likely that the effect of training is larger when behaviour-relevant stimuli are used in training tasks, as a specific association between the no-go/stop response and the target behaviour is being established, a comparison of the effect of behaviour-specific versus neutral training will help establish the efficacy of using tailored tasks.

**Training duration.** Within the inhibitory control training literature, one session of training is typically employed (Bowley et al., 2013; Houben et al., 2012; Jones & Field, 2012; Veling, Aarts, & Papies, 2011); however, the number of trials that a training session involves differs across studies. Currently there is no direct evidence that longer training sessions are more beneficial. Additionally, it may be the case that a point exists at which the benefits of training plateau and no new gains are achieved despite further training. Therefore, it is worthwhile examining how training duration, as reflected in the number of task trials, influences behaviour regulation, particularly to establish parsimonious interventions.

**Type of health behaviour.** It is possible that the effectiveness of inhibitory control training will differ according to the characteristics of the target health behaviour. For example, the results presented in Chapter 5 demonstrated a stronger relationship between inhibitory control and health risk behaviours such as snack consumption, compared to health enhancing behaviours such as fruit and vegetable consumption. Previous research has also demonstrated similar results with psychometric assessments of executive function (Mullan et al., 2014). Additionally, McEachan et al. (2010) offer a framework for classifying and predicting health-related behaviours based on the unique characteristics of the behaviour, suggesting that not all health behaviours have the same determinants. Therefore, inhibitory control training may produce different results simply based on the type of health behaviour that is being targeted.
Behaviour measurement. A methodological concern that may account for differences in effect sizes across studies is the way in which behaviour is measured. While self-report measures may be subject to reporting bias, they may offer a more externally valid assessment of behaviour than laboratory-based measures such as pseudo taste tests (Smyth et al., 2001), which have been used to measure alcohol and food consumption post-training (Bowley et al., 2013; Houben, 2011; Jones & Field, 2012). Determining whether training effects differ based on how behaviour is measured may elucidate the true nature of the training effect.

Longevity of training effect. If inhibitory control training does induce improved behavioural regulation, it is important to determine the consistency of these effects over time. While previous research has demonstrated improvements in behavioural regulation when behavioural measures are administered immediately post-training (Houben, 2011; Verbruggen et al., 2012), studies that have measured behaviour up to a week post-training, have producing both significant differences in health behaviour outcomes (Houben et al., 2012), and non-significant results (Bowley et al., 2013; Jones & Field, 2012). Given the lack of conclusive evidence regarding the longevity of the inhibitory control training effect on health behaviour, it is important to examine the extent to which the effect of training diminishes over time in a cumulative analysis correcting for methodological artefacts. This may assist in resolving the nature of the effect.

Present analysis

Given the psychological consequences and health risks of engaging in behaviours such as unhealthy eating and excessive alcohol consumption, there is a need to establish the efficacy of techniques designed to reduce such behaviours. This aim of this analysis is to determine the size and consistency of the effect of inhibitory control training on reducing harmful behaviours while correcting for study precision. A secondary aim is to determine the nature of the effect by examining several potential moderators that might account for any
heterogeneity in the training effect. Determining whether extraneous variables moderate the effect may assist in the development of effective intervention strategies to promote better regulation of health behaviours.

Inhibitory control is a multifaceted construct comprised of several similar yet distinct inhibitory processes (Friedman & Miyake, 2004), including response inhibition, cognitive inhibition, and interference control (Gray & McNaughton, 2000; Nigg, 2000). The current review will focus exclusively on response inhibition; the suppression of actions that interfere with goal-directed behaviour. This is due to the nature of the tasks used to assess and train this inhibitory process (i.e., GNG and SST). These tasks directly and uniquely demand response inhibition whereas other inhibitory control tasks, including the Flanker and the Stroop, demand other elements of inhibition (Spierer, Chavan, & Manuel, 2013). In addition, research aiming to change behaviour by training of self-control will not be considered for similar reasons (e.g., Muraven, 2010b; Oaten & Cheng, 2006a). Specifically, self-control training involves modifying an element of behaviour typically for a two-week period, such as maintaining the correct posture. While this action would demand inhibitory control, it is unclear whether other processes are also influencing behaviour change.

**Method**

*Information sources and search strategy*

A systematic literature search was conducted of electronic databases including PsycINFO, Medline, Scopus, and ProQuest Dissertations. The search period was from 1990 up to and including January 2014. The search terms used were: (go nogo OR go no-go OR stop signal OR stop-signal OR response inhibition OR inhibitory control) AND (training OR intervention OR modif*). Searches were limited to human studies, English language publications, and adult populations. In addition, reference sections of retrieved articles were examined, as were the reference sections of key narrative review articles of response
inhibition studies (Jones, Christiansen, Nederkoorn, Houben, & Field, 2013; Spierer et al., 2013). Finally, key authors and researchers in the field were contacted for any additional unpublished studies and data sets.

**Inclusion and exclusion criteria**

To be included in the analysis, studies needed to (1) include at least one session of SST or GNG task training; (2) adopt a randomised controlled design; (3) include a behavioural outcome measure; (4) contain sufficient statistical information to compute an effect size such as cell means and standard deviations, $F$ ratios, or $t$-statistics. When the relevant statistics were not reported for otherwise eligible studies, authors were contacted to obtain the necessary information.

There were no restrictions on the nature of behaviour measurement (i.e., self-report or objective behaviour), or publication status (i.e., available unpublished data were included). Studies that included two interacting intervention techniques in a single condition using a non-factorial design (e.g., GNG training and diary keeping) were also excluded. Non-experimental studies that used inhibitory control tasks to predict health outcomes or vice-versa were also excluded. Studies which included unsuitable measures of behavioural outcomes, such as those which used the same task or stimuli to assess transfer to behaviour, were also excluded.

**Information extracted and meta-analytic strategy**

Means and standard deviations of each intervention condition’s performance on behavioural outcomes were extracted when such information was provided in the manuscript. However, when unavailable, authors were contacted to provide this information. Where possible, pre and post measures of behavioural outcomes were extracted and effect sizes controlling for pre-scores were calculated. All information was entered into Excel spreadsheets. Data sets for two studies eligible for inclusion, but with insufficient data to compute
effect size, could not be obtained through direct contact with the authors (Guerrieri et al., 2012; Guerrieri et al., 2009). Additionally, effect sizes for the influence of training on one outcome measure could not be obtained from one study (Nagy, 2012).

Comprehensive Meta-Analysis v. 2.0 was used for calculating effect sizes and conducting all analyses including examining publication bias, heterogeneity, and moderation. The effect size metric employed in the current analysis was Cohen’s $d$ (Cohen, 1988), which represents the standardised mean difference score for experimental and control conditions. Although a systematic literature search was conducted, a random effects model was used in order to control for the possibility that relevant articles were missed (Borenstein, Hedges, & Rothstein, 2007). A random effects model is also recommended when samples across studies are heterogeneous, as was the case in the included studies (DerSimonian & Laird, 1986).

For each effect size a 95% confidence interval (CI$_{95}$) was calculated, and Cochrane’s $Q$ and $I^2$ statistics were used to explore heterogeneity (Huedo-Medina, Sánchez-Meca, Marin-Martínez, & Botella, 2006). $Q$ assessed the presence of heterogeneity. If $Q$ is statistically significant, heterogeneity is present. $I^2$ expressed heterogeneity as a percentage of the total variation across the included studies. $I^2$ values up to 25% indicated low heterogeneity, up to 50% indicated moderate heterogeneity, and up to 75% or higher indicated high heterogeneity (Higgins, Thompson, Deeks, & Altman, 2003). A moderator analysis was conducted in a mixed-effects model. This model generates information about the extent to which moderators influence the true effect sizes (Hunter & Schmidt, 2000).

**Moderator coding**

**GNG versus SST.** The influence of type of inhibitory control task on effectiveness of training was examined. Studies were categorised into those that adopted either GNG or SST as the training treatment. Tasks requiring participants to withhold a response to all members of a category was categorised as having used a GNG task. Tasks requiring participants to
withhold responding to a proportion of stimuli within a category were categorised as having used an SST. The types of stop-signals used in the SST (i.e., tone versus visual) were not differentiated between.

**Behaviour-specific versus neutral training task.** Tasks that included stimuli related to the target behaviour were coded as behaviour-specific training tasks, and tasks that used neutral stimuli were categorised as neutral training tasks. If studies included both types of tasks as separate conditions, and compared the performance of these conditions to the same control condition, only the behaviour-specific and control comparison was included in order to maintain independence of effect sizes. If studies included a condition in which participants were trained on both behaviour-specific and neutral stimuli concurrently, comparisons between this condition and behaviour-specific only inhibition conditions were not included due to potential confounds between behaviour-specific and neutral inhibition training. Finally, if the inhibitory control training condition was compared to a non-standard control condition, these comparisons were not included due to a lack of consistency across these additional control conditions.

**Type of task.** There was overlap between type of training task and behavioural specificity of training task in that no studies included a neutral GNG task. Therefore, a moderator variable was created that incorporated both of these elements. Studies were coded as using a GNG, an SST-specific, or an SST-neutral training task.

**Training duration.** In order to assess whether intensity of training influenced behavioural outcomes, a meta-regression was conducted with number of trials entered as a continuous predictor of the inhibitory control training effect size.

**Type of health behaviour.** A moderator analysis was conducted to determine whether the effect of inhibitory control training on behavioural outcomes differed according to the type of behaviour that was targeted. Originally, behaviours were to be categorised into health
risk or health enhancing behaviours; however, no included studies attempted to improve a health enhancing behaviour. As such, behaviours were categorised according to type of health risk behaviour: unhealthy eating, alcohol use, and gambling.

**Objective versus non-objective.** The measures used to assess differences in behaviour were generally objective or subject to bias. Objective measures included laboratory-based taste tests or choice tasks. Non-objective measures were primarily self-report. In one study, participants were given a small bag of palatable food to take home and return the next day after consuming as much or as little of the food as they liked (Veling et al., 2011). As this measure was subject to confound; for example, other individuals may have consumed the contents of the bag, this was considered a non-objective measure.

**Longevity of training effect.** A moderator variable was created to assess the time at which differences in behaviour were assessed. If measurement took place immediately after training this was categorised as immediate-assessment, while all other time frames were considered post-assessment. This ranged from one day to one week.

**Measurement of behaviour.** There was overlap between how and when behaviour was assessed in that immediately administered measures tended to be laboratory-based, whereas post-assessment measures tended to be self-report. Therefore, these two moderators were combined into one moderator that indicated both of these elements. Studies were categorised as immediate-objective, post-objective or post-non-objective.

**Risk of bias**

An effort was made to include unpublished studies and datasets, as including only published studies risks inflation of effects due to significant results potentially being more likely to be published (Hopewell, McDonald, Clarke, & Egger, 2007). Concerted efforts were also made to track down unreported effect sizes. Furthermore, when data used to compute effect sizes such as means, standard deviations, or sample sizes were not reported in
published articles, the authors were contacted in order to again avoid potential inflation. Finally, the fail-safe N (Rosenberg, 2005) was computed to estimate how many potential effects may be required to reduce the overall averaged corrected effect size to a trivial size. However, the fail-safe N has been shown to be fallible in detecting potential bias in effect sizes (Thornton & Lee, 2000). In fact, it is important to control for ‘small study’ effects, which may reflect a tendency for low-powered small studies to be included in published data sets. Such effects may be indicative of publication bias (Sterne, Egger, & Smith, 2001). This can be detected by examining the plot of the effect size against study precision, that is, the reciprocal of the standard error. The distribution should reflect a ‘funnel’ shape such that, larger studies appear close to the true effect size and smaller, and therefore more imprecise, studies fall further away and should be evenly distributed. Bias is present if values are not evenly distributed within the funnel or fall outside the funnel shape. Funnels for the effect sizes in the current study and moderator subgroups were computed. Additionally, Duval and Tweedie’s (2000) Trim and Fill procedure was applied to control for ‘small study’ effects in which studies with disproportionately large effects with small sample sizes that are not evenly distributed, or fall outside the funnel plot, are removed and ‘filled’ with hypothetical studies to revolve the uneven distribution. If the averaged corrected effect size remains unchanged after the application of the trim and fill, the sample of studies is said to be unaffected by publication bias.

Results

The literature search identified 16 studies, within 12 articles, that met the inclusion criteria; therefore, 16 independent tests of the training effect were included in the meta-analysis. The entire study selection process is displayed in Figure 6.1.
Figure 6.1. Flow diagram for the search and inclusion criteria for studies in the meta-analysis. Adapted from (Moher, Liberati, Tetzlaff, & Altman, 2009).
**Characteristics of included studies**

The mean sample size within the datasets was 61. Two studies included only a neutral inhibitory control training task (Verbruggen et al., 2012; Verbruggen et al., 2013). A further two included both a behaviour-specific condition and a neutral task training condition (Jones & Field, 2012; Nagy, 2012). In order to maintain independence of effect sizes, only the effect size for the behaviour-specific and control comparison was extracted and entered into the analysis. Two studies included a condition in which participants were trained on both behaviour-specific and neutral stimuli concurrently (Houben, 2011; Houben & Jansen, 2011). In addition, one study included a previously-established intervention strategy as a secondary control condition (Bowley et al., 2013), namely a Brief Alcohol Intervention (Hallett, Maycock, Kypri, Howat, & McManus, 2009), while another included a no-training condition in which participants immediately carried out the outcome measures (Verbruggen et al., 2012). Comparisons between inhibitory control training and these control conditions were not included due to the small number of studies utilising non-standard control conditions. Finally, one study measured behaviour using a task that included the same stimuli that participants were trained on, and was therefore not included due to the questionable generalisability of the findings (Veling et al., 2013a).

Three different types of behaviours were reported: alcohol consumption, unhealthy food consumption and gambling behaviour. The majority of studies used one measure of health behaviour to assess the effect of training on health behaviour. Particularly, several studies used a laboratory-based measure. The most frequently used laboratory-based measure was a pseudo taste test administered immediately after the training session. While some studies used both a laboratory-based and a self-report measure of health behaviour, this was confined to the studies examining the effect of training on alcohol consumption (Bowley et al., 2013; Houben, Nederkoorn, et al., 2011; Jones & Field, 2012; Nagy, 2012), where both a
pseudo taste test and the time-line follow back questionnaire (Sobell & Sobell, 1992) were used to assess differences in alcohol consumption between trained and non-trained conditions. For these studies, the mean of the effect size was taken. These studies, and one more (Houben et al., 2012), utilised a pre-post design to assess change in alcohol consumption. For these studies, the effect size was calculated after taking into account baseline alcohol consumption, rather than using post-training scores only. See Table 6.1 for characteristics and effect sizes of the included studies.
Table 6.1
Effect Sizes and Characteristics of Studies Included In the Meta-Analysis

<table>
<thead>
<tr>
<th>Study</th>
<th>Task</th>
<th>Behaviour</th>
<th>Training condition</th>
<th>Control condition</th>
<th>Sessions; trials in each session</th>
<th>Behavioural outcome &amp; result</th>
<th>Participants</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowley et al. (2013)</td>
<td>GNG; behaviour-specific</td>
<td>Alcohol consumption</td>
<td>Beer no-go</td>
<td>Beer go</td>
<td>1; 80</td>
<td>Less beer consumed in taste test, self-report alcohol consumption</td>
<td>59 undergraduates; drink beer regularly and have a preference for beer</td>
<td>.32a</td>
</tr>
<tr>
<td>Houben et al. (2012)</td>
<td>GNG; behaviour-specific</td>
<td>Alcohol consumption</td>
<td>Beer no-go</td>
<td>Beer go</td>
<td>1; 320</td>
<td>Lower self-reported alcohol consumption</td>
<td>57 heavy drinkers; have a preference for beer</td>
<td>.51b</td>
</tr>
<tr>
<td>Houben (2011)</td>
<td>SST; behaviour-specific;</td>
<td>Eating behaviour</td>
<td>snacks paired with</td>
<td>snacks paired with</td>
<td>1; 288</td>
<td>Snacks taste test</td>
<td>29 female undergraduates; positive attitudes/liking towards crisps, nuts and chocolate</td>
<td>.45</td>
</tr>
<tr>
<td></td>
<td>within-participants</td>
<td></td>
<td>stop</td>
<td>go</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houben and Jansen (2011)</td>
<td>GNG; behaviour-specific</td>
<td>Eating behaviour</td>
<td>chocolate no-go</td>
<td>chocolate go</td>
<td>1; 320</td>
<td>Chocolate taste test</td>
<td>63 female undergraduates; trait chocolate lovers</td>
<td>.54</td>
</tr>
<tr>
<td>Houben, Nederkoorn, et al. (2011)</td>
<td>GNG; behaviour-specific</td>
<td>Alcohol consumption</td>
<td>beer no-go</td>
<td>beer go</td>
<td>1; 80</td>
<td>Less beer consumed in taste test; lower self-reported alcohol consumption</td>
<td>52 heavy drinkers; have a preference for beer</td>
<td>.59ab</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Condition</td>
<td>Procedure</td>
<td>Sample Size</td>
<td>Effect Size</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
<td>-----------</td>
<td>------------</td>
<td>-------------</td>
<td>-------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jones and Field (2012; Study 1)</td>
<td>SST; behaviour-specific &amp; neutral</td>
<td>Alcohol consumption</td>
<td>alcohol paired with stop&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Told to ignore signal (go)</td>
<td>1; 240</td>
<td>Less alcohol consumed in taste test; self-report alcohol consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nagy (2012)</td>
<td>SST; behaviour-specific &amp; neutral</td>
<td>Alcohol consumption</td>
<td>alcohol paired with stop&lt;sup&gt;e&lt;/sup&gt;</td>
<td>no stop-signals</td>
<td>5; 192</td>
<td>alcohol taste test; self-report alcohol consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>van Koningsbruggen et al. (2013; Study 1)</td>
<td>GNG; behaviour-specific</td>
<td>Eating behaviour</td>
<td>sweets no-go</td>
<td>sweets go</td>
<td>1; 72</td>
<td>Less food serving behaviour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>van Koningsbruggen et al. (2013; Study 2)</td>
<td>GNG; behaviour-specific</td>
<td>Eating behaviour</td>
<td>sweets no-go</td>
<td>sweets go</td>
<td>1; 72</td>
<td>Less snacks dispensed in a virtual snack dispenser</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veling et al. (2011; Study 2)</td>
<td>GNG; behaviour-specific</td>
<td>Eating behaviour</td>
<td>sweets no-go</td>
<td>sweets go</td>
<td>1; 72</td>
<td>Candy consumption (take home bag)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veling, Aarts, and Stroebe (2013b; Study 1)</td>
<td>SST; behaviour-specific</td>
<td>Eating behaviour</td>
<td>snacks no-go</td>
<td>snacks go</td>
<td>1; 96</td>
<td>Fewer unhealthy choices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veling et al. (2013b; Study 2)</td>
<td>SST; behaviour-specific</td>
<td>Eating behaviour</td>
<td>snacks no-go</td>
<td>snacks go</td>
<td>1; 96</td>
<td>Fewer unhealthy choices under cognitive load</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> 90 staff and students; heavy social drinkers; liking of beer

<sup>b</sup> 45 heavy drinkers; n/a
<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Condition</th>
<th>Response Type</th>
<th>Session 1</th>
<th>Session 2</th>
<th>Sample Size</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbruggen et al. (2012; Study 2)</td>
<td>SST; neutral</td>
<td>Gambling</td>
<td>stop response</td>
<td>double response-go trials and push space bar</td>
<td>1; 720</td>
<td>Lower betting score</td>
<td>81 adults/ community sample</td>
</tr>
<tr>
<td>Verbruggen et al. (2012; Study 3)</td>
<td>SST; neutral</td>
<td>Gambling</td>
<td>stop response</td>
<td>double response-go trials and push space bar</td>
<td>1; 840</td>
<td>Lower betting score</td>
<td>54 adults/ community sample</td>
</tr>
<tr>
<td>Verbruggen et al. (2013; Study 1)</td>
<td>SST; neutral</td>
<td>Gambling</td>
<td>stop response</td>
<td>double response-go trials and push space bar</td>
<td>1; 840</td>
<td>betting score</td>
<td>59 adults/ community sample</td>
</tr>
<tr>
<td>Verbruggen et al. (2013; Study 2)</td>
<td>SST; neutral</td>
<td>Gambling</td>
<td>stop response</td>
<td>double response-go trials and push space bar</td>
<td>2; 720. Session 2 24h after session 1</td>
<td>betting score</td>
<td>48 undergraduates</td>
</tr>
</tbody>
</table>

Notes: significant results are presented in boldface; non-significant results are presented with strikethrough; trend in italics; GNG = go/no-go task; SST = stop-signal task. * $p < .05$; ** $p < .01$. \(^a\) Combined effect size from self-report and laboratory-based measure, \(^b\) Effect size calculated controlling for pre-scores on self-report measure, \(^c\) Study also included additional control condition: Brief Alcohol Intervention, \(^d\) Study also included control condition in which behaviour specific and neutral stimuli were training concurrently, \(^e\) Study also included inhibitory control training condition with neutral stimuli, \(^f\) Study also included a no-training condition in which outcome measures were immediately assessed.
**Overall training effect**

The averaged corrected standardised mean difference for response inhibition training on health behaviour was $d^+ = 0.438$, CI$_{95} = [0.267, 0.609]$, $p < .001$. This represents an effect that falls between the small (0.20) and medium (0.50) effect size guidelines proposed by Cohen (1988). Two of the 16 effect sizes were negative in valence, indicating that training produced a detrimental effect on behavioural outcomes. See Figure 6.2 for forest plot of the effect of inhibitory control training on health behaviour. Tests for heterogeneity indicated that there was substantial heterogeneity in the effect size across studies, which was unattributed to sampling error $Q(15) = 23.041$, $p = .038$; $I^2 = 34.99\%$, indicating the likely presence of extraneous moderators. In addition, the effect size could also be considered non-trivial given that the confidence interval did not include zero. The fail safe sample-size ($N_{FS} = 147$) exceeded the suggested cut off value, indicating that it was highly unlikely that sufficient studies with null effects exist which, if included, could reduce the size of the effect. However, inspection of funnel plot and application of Duval and Tweedie’s (2000) Trim and Fill method to correct for small-study bias suggested that four studies were missing on the left side of the mean effect size. This indicated that the included small-studies, which fell to the right of the mean, may be inflating the effect size. Using the Trim and Fill method to adjust for small-study bias, the imputed point estimate is $d^+ = 0.335$, CI$_{95} = [0.166, 0.503]$, $p < .001$. 
<table>
<thead>
<tr>
<th>Study</th>
<th>$d$</th>
<th>LL</th>
<th>UL</th>
<th>$p$</th>
<th>-1.00</th>
<th>-.500</th>
<th>.000</th>
<th>.500</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowley et al. (2013)</td>
<td>0.324</td>
<td>-0.308</td>
<td>0.956</td>
<td>0.315</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houben et al. (2012)</td>
<td>0.509</td>
<td>0.118</td>
<td>0.900</td>
<td>0.011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houben (2011)</td>
<td>0.446</td>
<td>-0.075</td>
<td>0.967</td>
<td>0.093</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houben and Jansen (2011)</td>
<td>0.540</td>
<td>-0.083</td>
<td>1.163</td>
<td>0.090</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houben, Nederkoorn et al. (2011)</td>
<td>0.585</td>
<td>0.033</td>
<td>1.138</td>
<td>0.038</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jones and Field (2012; Study 1)</td>
<td>0.263</td>
<td>-0.270</td>
<td>0.796</td>
<td>0.334</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nagy (2012)</td>
<td>0.536</td>
<td>-0.197</td>
<td>1.269</td>
<td>0.152</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>van Koningsbruggen et al. (2013; Study 1)</td>
<td>0.775</td>
<td>0.175</td>
<td>1.375</td>
<td>0.011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>van Koningsbruggen et al. (2013; Study 2)</td>
<td>0.761</td>
<td>0.162</td>
<td>1.360</td>
<td>0.013</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veling et al. (2011; Study 2)</td>
<td>0.265</td>
<td>-0.316</td>
<td>0.846</td>
<td>0.371</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veling, Aarts, and Stroebe (2013b; Study 1)</td>
<td>0.716</td>
<td>0.106</td>
<td>1.326</td>
<td>0.022</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veling, Aarts, and Stroebe (2013b; Study 2)</td>
<td>0.539</td>
<td>0.089</td>
<td>0.988</td>
<td>0.019</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbruggen et al. (2012; Study 2)</td>
<td>0.902</td>
<td>0.342</td>
<td>1.462</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbruggen et al. (2012; Study 3)</td>
<td>0.602</td>
<td>0.057</td>
<td>1.147</td>
<td>0.031</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbruggen et al. (2013; Study 1)</td>
<td>-0.231</td>
<td>-0.743</td>
<td>0.281</td>
<td>0.376</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbruggen et al. (2013; Study 2)</td>
<td>-0.425</td>
<td>-0.997</td>
<td>0.148</td>
<td>0.146</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total effect</td>
<td>0.438</td>
<td>0.267</td>
<td>0.609</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 6.2. Forest plot of effect sizes for inhibitory control training and health outcomes*
Moderator analyses

*GNG versus SST.* The effect of training on health outcomes did not differ significantly according to whether the GNG, $d^r = 0.534$, CI$_{95}$ = [0.327, 0.741], $p < .001$, or the SST, $d^r = 0.365$, CI$_{95}$ = [0.081, 0.649], $p = .012$, was used as the training task. However, while the effect of GNG training on behavioural outcomes was homogenous, $Q(6) = 2.466$, $p = .872$, $I^2 = 0.00$, the effect of SST training on behavioural outcomes was effected by substantial heterogeneity, $Q(8) = 19.061$, $p = .015$, $I^2 = 58.03\%$, indicating that within studies using the SST task, further factors may account for the variability in the effect sizes. See Table 2 for additional moderator statistics.
### Table 6.2

**Moderator Analysis of the Size of the Effect of Inhibitory Control Training on Health Behaviour**

<table>
<thead>
<tr>
<th>Moderator</th>
<th>k</th>
<th>N</th>
<th>d</th>
<th>LL</th>
<th>UL</th>
<th>SE</th>
<th>Var</th>
<th>Q</th>
<th>$I^2$</th>
<th>Tau²</th>
<th>SE</th>
<th>Var</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNG task vs SST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GNG task</td>
<td>7</td>
<td>328</td>
<td>.534</td>
<td>.327</td>
<td>.741</td>
<td>.105</td>
<td>.011</td>
<td>2.466</td>
<td>.000</td>
<td>.000</td>
<td>.046</td>
<td>.002</td>
</tr>
<tr>
<td>SST</td>
<td>9</td>
<td>486</td>
<td>.365</td>
<td>.081</td>
<td>.649</td>
<td>.145</td>
<td>.081</td>
<td>19.061</td>
<td>58.029</td>
<td>.108</td>
<td>.094</td>
<td>.009</td>
</tr>
<tr>
<td>Behaviour-specific vs neutral</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Behaviour-specific</td>
<td>12</td>
<td>599</td>
<td>.515</td>
<td>.357</td>
<td>.673</td>
<td>.081</td>
<td>.006</td>
<td>3.855</td>
<td>.000</td>
<td>.000</td>
<td>.034</td>
<td>.001</td>
</tr>
<tr>
<td>Neutral</td>
<td>4</td>
<td>215</td>
<td>.211</td>
<td>-.409</td>
<td>.831</td>
<td>.316</td>
<td>.100</td>
<td>15.422</td>
<td>80.547</td>
<td>.322</td>
<td>.327</td>
<td>.107</td>
</tr>
<tr>
<td>Type of task</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GNG task_Behaviour-specific</td>
<td>7</td>
<td>328</td>
<td>.534</td>
<td>.327</td>
<td>.741</td>
<td>.105</td>
<td>.011</td>
<td>2.466</td>
<td>.000</td>
<td>.000</td>
<td>.046</td>
<td>.002</td>
</tr>
<tr>
<td>SST_Behaviour-specific</td>
<td>5</td>
<td>271</td>
<td>.448</td>
<td>.244</td>
<td>.733</td>
<td>.125</td>
<td>.016</td>
<td>1.310</td>
<td>.000</td>
<td>.000</td>
<td>.056</td>
<td>.003</td>
</tr>
<tr>
<td>SST_Neutral</td>
<td>4</td>
<td>215</td>
<td>.211</td>
<td>-.409</td>
<td>.831</td>
<td>.316</td>
<td>.100</td>
<td>15.422</td>
<td>80.547</td>
<td>.322</td>
<td>.327</td>
<td>.107</td>
</tr>
<tr>
<td>Type of behaviour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>5</td>
<td>239</td>
<td>.451</td>
<td>.231</td>
<td>.689</td>
<td>.121</td>
<td>.015</td>
<td>.997</td>
<td>.000</td>
<td>.000</td>
<td>.055</td>
<td>.003</td>
</tr>
<tr>
<td>Eating</td>
<td>7</td>
<td>360</td>
<td>.566</td>
<td>.354</td>
<td>.777</td>
<td>.108</td>
<td>.012</td>
<td>2.359</td>
<td>.000</td>
<td>.000</td>
<td>.047</td>
<td>.002</td>
</tr>
<tr>
<td>Gambling</td>
<td>4</td>
<td>215</td>
<td>.211</td>
<td>-.409</td>
<td>.831</td>
<td>.316</td>
<td>.100</td>
<td>15.422</td>
<td>80.547</td>
<td>.322</td>
<td>.327</td>
<td>.107</td>
</tr>
</tbody>
</table>
### Objective vs. non-objective

<table>
<thead>
<tr>
<th></th>
<th>Objective</th>
<th>Non-objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of follow up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediate</td>
<td>10 529 .454 .182 .727 .139 .019 21.387 58.500 .112 .091 .008</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>3 133 .450 .153 .747 .151 .023 .530 .000 .000 .080 .006</td>
<td></td>
</tr>
</tbody>
</table>

### Measurement

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Objective_Immediate</th>
<th>Objective_Post</th>
<th>Non_Objective_Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of follow up</td>
<td>Immediate</td>
<td>Post</td>
<td></td>
</tr>
<tr>
<td>Objective_Immediate</td>
<td>7 376 .630 .423 .838 .106 .011 1.893 .000 .000 .046 .002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective_Post</td>
<td>3 153 .030 -.668 .729 .356 .127 9.310 78.517 .299 .381 .145</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non_Objective_Post</td>
<td>3 133 .450 .153 .747 .151 .023 .530 .000 .000 .080 .006</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* GNG task_Behaviour-specific = behaviour-specific go/no-go task; SST_Behaviour-specific = behaviour specific stop-signal task; SST_Neutral = neutral stop-signal task; Objective_Immediate = objective outcome measure administered immediately after training session; Objective_Post = objective outcome measure administered at least 1 day after training session.
**Behaviour-specific versus neutral-training task.** The effect of training on health outcomes, when the task was tailored to the specific behaviour, resulted in a medium effect of $d^r = 0.515$, CI$_{95} = [0.357, 0.673]$, $p < .001$. However, the effect of training using a neutral response-inhibition task was not significant, $d^r = 0.211$, CI$_{95} = [-0.409, 0.831]$, $p = .505$.

While the effect of behaviour-specific training was homogenous, $Q(11) = 3.855$, $p = .974$, $I^2 = 0.00\%$, the effect of neutral training was significantly heterogeneous, $Q(3) = 15.422$, $p = .001$, $I^2 = 80.55\%$.

**Type of task.** Examining the effect of training according to both the type of task, and whether the task was tailored or neutral, revealed that both the tailored version of the GNG, $d^r = 0.534$, CI$_{95} = [0.327, 0.741]$, $p < .001$, and the tailored version of the SST, $d^r = 0.488$, CI$_{95} = [0.244, 0.733]$, $p < .001$, yielded significant effects for improvement in behavioural outcomes. In addition, both these sets of effect sizes were homogenous, $Q(6) = 2.466$, $p = .872$, $I^2 = 0.00$; and $Q(4) = 1.310$, $p = .860$, $I^2 = 0.00$, respectively. However, the effect of neutral SST training on health behaviour did not appear to be significant, $d^r = 0.211$, CI$_{95} = [-0.409, 0.831]$, $p = .505$, but was significantly heterogeneous, $Q(3) = 15.422$, $p = .001$, $I^2 = 80.547$, indicating that other factors may account for the variance in effect sizes within this category of tasks.

**Training duration.** Length of training, indexed as number of trials, was treated as a continuous moderator of the inhibitory control training effect. A linear regression analysis was conducted, with the training effect size as the dependent variable and number of trials as an independent continuous predictor. The analysis did not yield a significant effect for task duration on the training effect ($\beta = -.0004$, $z = -1.569$, $p = .117$).

**Type of health behaviour.** Examining the effect of training according to each type of behaviour revealed that training produced significant effects for both improvement in alcohol consumption, $d^r = 0.451$, CI$_{95} = [0.231, 0.689]$, $p < .001$, and eating behaviour, $d^r = 0.566$, 122
CI95 = [0.354, 0.777], p < .001. The effect of training on alcohol consumption appeared to yield an effect size between the small-to-medium guideline, while the effect of training on eating behaviour appeared to yield a medium effect. However, as the confidence intervals overlapped, these effect sizes were not substantively different. In addition, both sets of effect sizes for alcohol consumption, \( Q(4) = 0.997, p = .910, I^2 = 0.00 \), and eating behaviour, \( Q(6) = 2.359, p = .884, I^2 = 0.00 \), were sufficiently homogenous. The confidence interval for the effect of training on gambling outcomes included the value of zero; therefore, this effect could be considered trivial in size and it is questionable whether it is a real effect at all, \( d^r = 0.211, CI_{95} = [-0.409, 0.831], p = .505 \). There was significant heterogeneity within the effect sizes yielded from the gambling studies, \( Q(3) = 15.422, p = .001, I^2 = 80.547 \). However, as the confidence intervals overlapped, this effect was not substantially smaller than that obtained for the alcohol consumption or eating behaviour studies.

**Objective versus non-objective.** It appeared that training produced similar effects on behaviour assessed through objective measures, \( d^r = 0.454, CI_{95} = [0.182, 0.727], p = .001 \); compared to non-objective measures, \( d^r = 0.450, CI_{95} = [0.153, 0.747], p = .003 \). While non-objective measures appeared to produce homogenous effect sizes, \( Q(2) = 0.530, p < .001, I^2 = 0.00\% \), objective measures appeared to be significantly heterogeneous, \( Q(9) = 21.687, p = .010, I^2 = 58.50\% \).

**Longevity of training effect.** The time at which behaviour was measured appeared to influence the size of the effect of training on behavioural outcomes. Behaviour measured immediately resulted in a medium effect size of \( d^r = 0.630, CI_{95} = [0.423, 0.838], p < .001 \), with confidence intervals that excluded zero. Whereas behaviour measured at a later time point was substantially smaller and included zero raising the question as to whether this is a true effect, \( d^r = 0.230, CI_{95} = [-0.145, 0.605], p = .228 \). While the effect size for immediately
measured behaviour was homogenous, $Q(6) = 1.893, p = .929, I^2 = 0.00\%$, the effect size for behaviour measured at a later time point was not, $Q(5) = 13.944, p = .016, I^2 = 64.14\%$.

**Measurement of behaviour.** Examining the effect size based on when and how behaviour was measured revealed that laboratory-based tasks administered immediately after training yielded larger effect sizes, $d^+ = 0.646, CI_{95} = [0.450, 0.842], p < .001; Q(7) = 2.033, p = .955, I^2 = 0.00\%$, than that administered at a later point in time, $d^+ = -0.317, CI_{95} = [-0.699, 0.064], p = .103; Q(1) = 0.244, p = .621, I^2 = 0.00\%$, as indicated by the lack of overlap in confidence intervals. Self-report measures administered at a later point in time yielded a small-to-medium effect size, $d^+ = 0.450, CI_{95} = [0.153, 0.747], p = .003; Q(2) = 0.530, p = .767, I^2 = 0.00\%$. While both immediately administered laboratory-based measures of behaviour and self-report measures were non-zero according to confidence intervals, the effect size for laboratory measures administered at a later time point was not, raising questions as to whether this is a true effect. All effect sizes were homogenous.

**Discussion**

The aim of this meta-analysis was to conduct a quantitative cumulative analysis of studies examining the effect of inhibitory control training on health-related behavioural outcomes. The main purpose was to establish the size of the effect across studies, and whether it was non-trivial after correcting for study precision using meta-analytic techniques. Also of interest was whether task parameters and methodological characteristics influenced the size and consistency of the training effect. The meta-analysis of the overall training effect produced an effect size between the small-to-medium guideline effect sizes proposed by Cohen (1988). Confidence intervals about the effect did not include the value of zero indicating that the effect size across studies was non-trivial and likely to be a ‘real’ effect. However, the effect size was subject to substantial heterogeneity, indicating unexplained variance in the effect size across studies and the presence of extraneous moderators.
Moderation analyses revealed that training that used either a behaviour-specific GNG, or a behaviour-specific SST, produced significant medium effect sizes. However, studies that employed training on neutral-stimuli tasks did not produce non-zero effect sizes, questioning the propensity of these tasks to produce effects. In general, training that utilised the SST did not appear to differ from training that utilised the GNG, suggesting that if these tasks produce improvements in behaviour via different mechanisms, these mechanisms do not differ in their effectiveness. Further, it appeared that the length of the training session did not influence the size of the training effect. In terms of whether inhibitory control training was more beneficial to a particular behaviour, analyses revealed non-zero effects for both eating behaviour and alcohol consumption, but not for gambling behaviour. Outcomes that were measured immediately after training appeared to produce medium-sized non-zero effects, whereas those measured at a later time point were not significant. When considering the method of measurement, immediately administered objective measures produced a medium-sized effect, whereas objective measures that were administered a least one day after training did not result in a non-zero effect. Finally, non-objective measures, which were all administered at least one day after training, resulted in a small-to-medium sized effect.

**Type of task**

Inhibitory control training that utilised either a behaviour-specific GNG, or a behaviour-specific SST, produced medium effect sizes, which were homogenous. This suggests that interventions aiming to improve engagement in harmful behaviours through inhibitory control training can employ either of the two tasks. Extrapolating these results, it may be inferred that both means of improving health behaviour, as suggested by dual-systems approaches: reducing the influence of the impulsive system or strengthening self-regulation (Friese et al., 2011), may result in comparable benefits. However, due to the limited number of studies that included additional measures to assess these potential mechanisms, it was not
possible to test this assumption. In order to address this concern, future research should aim to examine the mechanisms by which both GNG training and SST training influence behaviour. Namely, the conflicting findings of Bowley et al. (2013) and Houben et al. (2012) need to be consolidated. While Houben et al. (2012) demonstrated that differences in IAT performance mediated the influence of training on alcohol consumption, Bowley et al. (2013) were unable to replicate this effect, questioning whether GNG training does in fact influence evaluations of health-related stimuli, and whether this is responsible for differences in health behaviour. Additionally, the mechanism by which SST training influences behaviour has received limited attention. Nagy (2012) attempted to measure improvement on neutral SST performance after behaviour-specific SST training, demonstrating that all conditions improved on this task. It is possible that due to the similarity between training and transfer task, any improvement in inhibitory control as masked by practice effects. Future research should employ an alternative measure of inhibitory control, such as the Stroop task, in order to assess changes in inhibitory control after SST training.

Results of the meta-analysis appear to confirm the assumption that the inhibitory control training task needs to be behaviour-specific in order to influence the targeted behaviour. Overall, studies that included a neutral task did not produce substantial effect sizes. This implies that exercising inhibitory control in general is not enough to influence behaviour. While inhibitory control may improve, behaviour change may not occur because this improvement in inhibitory control is not directed toward a specific behaviour. In order to confirm this, studies aiming to influence behaviour through inhibitory control training should include both a behaviour-specific and neutral training condition as well as an additional measure of inhibitory control. Behaviour-specific training should result in improved performance on the additional inhibitory measure, as well as improvement in behaviour, whereas neutral training should only demonstrate improvement on the inhibitory control task.
**Length of training**

No studies have systematically examined whether the length of inhibitory control training influences the strength of behavioural outcomes. Current results indicate that longer training sessions did not produce larger effects. However, it is worth noting that many other factors within the included studies may have contributed to the unsubstantial effect. Studies with the longest training sessions tended to utilise neutral training tasks. An additional analysis was conducted to examine the influence of length of training on differences in behavioural outcomes only within studies that utilised a behaviour-specific task, and measured behaviour immediately, yet no moderating effect was detected. Future studies should systematically vary the number of trials and number of sessions in order to determine if more training results in greater benefits to behavioural outcomes.

**Behaviour**

It appears that behaviours such as unhealthy eating and alcohol consumption are more suited to inhibitory control training than compulsive gambling. However, this may be confounded by the fact that all studies on compulsive gambling utilised a neutral training task. As such, future research aiming to change compulsive gambling behaviour should develop and utilise a behaviour-specific task. Alternatively, it may be the case that the samples used in compulsive gambling studies were not suitable targets for inhibitory control training as they were community volunteers who were not necessarily compulsive gamblers, or did not necessarily have a preference for compulsive gambling. Conversely, the majority of the remaining studies recruited a sample that had a preference for the target behaviour. Hence, these samples had difficulty regulating that behaviour and would therefore benefit from training. For example, Bowley et al. (2013) aimed to change drinking behaviour through training on a GNG that included beer stimuli and therefore recruited those who had a preference for beer and regularly drank this particular alcohol. Future studies with the aim of
reducing gambling behaviour through inhibitory control training should target individuals with compulsive gambling tendencies.

**Stability of effect**

Results appear to indicate that differences in behaviour between those who received inhibitory control training and those who received some other form of training, are strongest when measured immediately. Specifically, when the effect of immediately administered objective measures of behaviour was compared to objective measures administered post-training; it was revealed that the latter effect was not significant. Additionally, while non-objective measures that were administered post-training appear to produce small-to-medium effects, this may be due to the method of measurement. Namely, self-report measures such as the time line follow back questionnaire (Sobell & Sobell, 1992), may be subject to reporting bias and thus produce an inflated effect size. While Verbruggen et al. (2013) attempted to systematically demonstrate that the effect of training does not persist over time, this study employed a neutral SST. The results of this meta-analysis suggest that training using a neutral inhibitory control task is not as effective as training using a behaviour-specific inhibitory control task. Therefore, it is recommended that future research systematically examines whether the effects of training with a behaviour-specific task persist over time.

**Strengths and limitations**

This is the first study to systematically synthesise the literature on inhibitory control training and behavioural outcomes. A strength of the current analysis was the extensive exploration of moderator effects to determine the source of inconsistencies in effect sizes. Additionally, the broad search strategy and inclusion of unpublished works ensured that the overall effect size was not inflated due to significant effects being more likely to be published. However, the present analysis included effect sizes that were based on relatively
small samples of studies, which may have inflated the overall effect size. Therefore, caution needs to be exercised when interpreting some of the reported effects.

In addition, the present analysis did not include outcomes such as differences in brain activation as demonstrated by EEG, such as that presented in Bowley et al. (2013). While the primary aim of the present analysis was to examine the effect of training on behavioural outcomes, such as alcohol consumption and eating behaviour, it may be worthwhile to systematically review the influence of inhibitory control training on neurophysiological outcomes and brain plasticity, particularly to further elucidate the mechanisms by which training may influence behaviour (for a narrative review, see: Spierer et al., 2013). While some studies did attempt to examine potential mechanisms by which training improved behaviour (Bowley et al., 2013; Houben et al., 2012; Houben, Nederkoorn, et al., 2011; Nagy, 2012), there were too few to conduct an analysis of the size of the effect of training, and further, none of the included studies attempted to determine the mechanism by which training improves eating behaviour.

Additionally, only two studies included an alternative inhibitory control task to assess whether training influenced inhibitory control, and if this improvement is responsible for changes in behaviour (Houben et al., 2012; Nagy, 2012). As mentioned previously, the findings of Nagy (2012) demonstrated that all conditions improved on neutral SST performance after SST training; however, this may have been due to the similarity between training task and transfer task. Houben et al. (2012) trained participants on a GNG and also measured SST performance but found no differences in SST performance between those who received training and the control condition. However, it could be argued that the control condition also exercised inhibitory control as participants in this condition were required to withhold responses to neutral stimuli, thus accounting for the lack of significant differences in inhibitory control. To examine whether GNG or SST training improves inhibitory control,
a third condition must be included that does not require the inhibition of responses. Finally, few studies included a pre-post design to assess change in behaviour; as such, the results of the present meta-analysis primarily reflect differences in behaviour between conditions. To address this concern, future studies should attempt to include measures that allow for pre- and post-intervention assessment of behavioural outcomes.

**Conclusions**

The present meta-analysis provides evidence that inhibitory control training results in differences in behavioural outcomes. Evidence indicates that both the GNG and the SST are effective at reducing health-compromising behaviours such as alcohol consumption and unhealthy eating. However, these tasks need to be tailored to the target behaviour in order to be successful. While it appears that length of training does not influence the size of the effect, and that the effects do not persist long after the training session, these elements need to be systematically examined in order to reach any firm conclusions. Determining the optimal length of training, and whether these effects transfer to everyday behaviour, would provide the basis for cost-effective and efficacious methods to promote health behaviour.
Chapter 7 – Inhibitory control training and eating behaviour: Addressing remaining questions

In the previous chapter, an examination of whether inhibitory control training can improve health behaviour was provided. In the majority of studies reviewed, training resulted in differences in behavioural outcomes between trained and non-trained participants. However, within the studies examining the effect of inhibitory control training on eating behaviour, none measured change in eating behaviour, nor included ecologically valid measures of eating behaviour. Further, few of these studies included alternative measures of inhibitory control, or other potential mechanisms, in order to establish the means by which inhibitory control training results in differences in eating behaviour. This chapter presents the results of an inhibitory control training intervention designed to not only improve eating behaviour but also address the concerns raised by this review.

Improvement in inhibitory control

The results of the meta-analysis presented in Chapter 6 demonstrated that both GNG training and SST were effective at producing differences in health behaviour; however; few studies examined the mechanism by which training influenced health behaviour. As discussed in Chapter 3, dual-systems approaches to explaining behaviour suggest that there are three routes by which behaviour change can occur (Hofmann, Friese, et al., 2008; Strack & Deutsch, 2004). Firstly, by changing the contents of the reflective system (i.e., changing explicit attitudes or increasing intentions to perform a behaviour), secondly, by changing the contents of the impulsive system (i.e., changing implicit evaluations associated with a behaviour), and thirdly, by increasing self-regulatory capacity (Friese et al., 2011; Hofmann, Friese, & Roefs, 2009). The studies that did attempt to establish the mechanisms underlying inhibitory control training primarily focused on the impulsive route (Bowley et al., 2013; Houben et al., 2012; Houben, Nederkoorn, et al., 2011), suggesting that GNG training results
in the devaluation of stimuli associated with the target behaviour and that this is responsible for health behaviour change, rather than an increase in self-regulatory capacity as measured by an SST (Houben et al., 2012). Studies examining the mechanism by which SST training improves health behaviour are scarce. Nagy (2012) suggested that SST training improves behaviour by increasing self-regulatory capacity; however, findings did not support this assumption. Though, as discussed in Chapter 6, this may have been due to similarities between the transfer task and the training task, such that any improvement in inhibitory control may have been masked by practice effects (Nagy, 2012). Consequently, it remains unclear whether SST training improves inhibitory control and if this improvement is responsible for changes in health behaviour.

The experimental design of previous SST training studies does not allow for the examination of whether training improves inhibitory control. The control condition that has typically been used (e.g., Guerrieri et al., 2012; Houben & Jansen, 2011; Jones & Field, 2012), involves completing an SST with the same number of stop-signals as that used in the training condition; however the stop-signals are not contingent on any one type of stimuli (i.e., general inhibitory control training). As such participants in both the training and control conditions are exercising the same amount of inhibitory control, and therefore, would both be expected to evidence improvements on an inhibitory control transfer task. In order to elucidate whether SST training does improve inhibitory control, the experimental design should include another condition in which inhibition is not required. Based on the results of the meta-analysis presented in Chapter 6, which indicated that training needed to be behaviour-specific in order to engender differences in health behaviour, it would be expected that while both behaviour-specific and general training conditions may demonstrate improvement in inhibitory control, only the condition in which inhibitory control towards target stimuli has been trained will result in improvements in eating behaviour.
Decrease in vulnerability to depletion

Dual-systems approaches conceptualise the ability to self-regulate in terms of both baseline capacity (i.e., performance on inhibitory control tasks) and situational capacity (i.e., vulnerability to depletion; Hofmann, Friese, et al., 2008). It is proposed that SST training may not only influence eating behaviour by improving baseline capacity, as described above, but also by decreasing vulnerability to depletion. Depletion has been shown to undermine the influence of the reflective system and result in greater consumption of high-calorie foods (Hofmann, Rauch, & Gawronski, 2007; Vohs & Heatherton, 2000). This is said to be due to the nature of self-regulation, wherein it is suggested that self-regulation relies on a limited resource that becomes temporarily depleted after exertion and compromises the ability to engage in further acts requiring self-regulation (Baumeister, Vohs, et al., 2007). Given that goal-directed behaviours are rarely performed in isolation, or without the influence of external stressors—two factors that lead to depletion and compromise the capacity to enact goal-directed behaviour (Hagger, Wood, Stiff, & Chatzisarantis, 2009), the ability to exercise self-regulation after depletion is essential to enacting health goals.

Further, vulnerability to depletion has been shown to decrease after behaviour regulation training (Muraven, 2010a). Behaviour regulation training involves regulating an element of behaviour that is unrelated to the target behaviour, such as speech, posture, or mood, for a period of time in order to improve self-regulation and consequently health behaviour (Muraven, Baumeister, & Tice, 1999; Oaten & Cheng, 2006b). For example, Muraven et al. (1999) measured participants’ performance on a handgrip task before and after a thought suppression task, and demonstrated a depletion effect such that performance post-thought suppression was significantly impaired. However, following behaviour regulation training, in which participants monitored their posture or mood for a two-week period, this detriment was not as pronounced, indicating that participants’ who completed the training
were less vulnerable to depletion. Oaten and Cheng (2006a) demonstrated similar effects while additionally demonstrating that this improvement transferred to a variety of self-reported health behaviours, including improvements in healthy eating, and decreases in smoking and binge drinking. These results indicate that vulnerability to depletion can be decreased, and suggest that this decrease may result in health behaviour change. Therefore, it may be worthwhile to examine whether behaviour-specific SST training not only improves inhibitory control capacity but also decreases vulnerability to depletion, and to examine whether change in this element of self-regulation accounts for change in health behaviour.

**Addressing additional concerns**

The results of the meta-analysis presented in Chapter 6 revealed a number of additional factors that need to be considered when determining the efficacy of SST training in the improvement of eating behaviour. The first concerns the measurement of eating behaviour. Previous research has assessed differences in eating behaviour between trained and non-trained participants rather than change in eating behaviour (Houben, 2011; Houben & Jansen, 2011; Veling et al., 2011; Veling et al., 2013b). As such, it is important to utilise a measure that allows for pre- and post-intervention assessment of behavioural outcomes. Additionally, measures that have been previously used to assess differences in eating behaviour, namely, pseudo taste tests (Houben, 2011; Houben & Jansen, 2011) may not be ecologically valid (Smyth et al., 2001). While self-report food frequency questionnaires may be subject to social desirability biases, they offer a less artificial measure of eating behaviour (Thompson & Subar, 2013). The second important consideration is the number of SST training sessions that are used. While a single training session has been shown to result in differences between trained and non-trained participants in an immediately administered pseudo taste test (Houben, 2011), one session may not be enough to change eating behaviour outside the laboratory. Indeed, Muraven (2010b) demonstrated change in biochemically
verified smoking behaviour after two weeks of behaviour regulation training, suggesting that a similar training period may be required to improve behaviour outside the laboratory.

**Aims and hypotheses**

The aim of this study was to improve self-reported eating behaviour through SST training. A secondary aim was to determine the mechanism by which SST training may improve health behaviour, by examining the extent to which training effects can be attributed to improvements in inhibitory control and/or a decreased vulnerability to depletion.

In order to achieve these aims three conditions, each with a different version of the SST, were included: (1) *behaviour-specific inhibition* condition in which the stop-signals were paired only with unhealthy food stimuli, (2) *general inhibition* condition that replicated the control condition used in previous research in which the same stimuli and proportion of stop-signals were used; however, the stop-signals were not contingent on a particular category of stimuli, and (3) *control* condition that included the same stimuli as other conditions but without stop-signals. It was hypothesised that inhibitory control would improve in both the behaviour-specific inhibition and general inhibition conditions compared to the control. Similarly, it was expected that vulnerability to depletion would improve in both the behaviour-specific inhibition and general inhibition conditions compared to the control. Improvement in eating behaviour was only expected in the behaviour-specific inhibition condition. Finally, it was expected that changes in inhibitory control and changes in vulnerability to depletion would mediate the effect of behaviour-specific inhibition training on changes in eating behaviour.
Methods

Participants

Eighty-two undergraduate students from a variety of disciplines (age = 20.43 years, $SD = 4.86$; BMI = 22.62, $SD = 2.64$; 66 females) were recruited to participate in a study in exchange for course credit. University students were recruited as this population often eats unhealthily, and are at a greater risk of weight gain than other populations (Racette et al., 2005; Strong et al., 2008). The number of participants recruited was based on an a-priori power analysis using G-Power 3 software (Faul, Erdfelder, Lang, & Buchner, 2007), which indicated that a sample size of 69 would be sufficient to detect a small to medium (0.15) interaction effect between three conditions at two time points with a power of .80 and an alpha of .05. While the meta-analysis revealed that the overall training effect was of medium size, sample size in this study was calculated for a smaller effect size based on the finding that measures that were not administered immediately after training resulted in smaller effect sizes.

Inclusion criteria for the current study included having the intention to change dietary behaviour, not colour blind, fluent in English, and having access to the internet. Additionally, participants were not invited to partake in the study if they indicated that they had a current or prior diagnosis of an eating disorder. Participants were randomly allocated to one of three conditions: behaviour-specific inhibition ($n = 29$), general inhibition ($n = 25$), and control ($n = 28$) by clicking a URL, which randomly directed them to one of three pages. The university’s Human Research Ethics Committee approved the study (see Appendix A) and participants provided informed consent prior to participation.
Materials and measures

**BMI & Eating Behaviour.** BMI was calculated from participants’ self-reported height and weight. Saturated fat intake was measured using the 17-items relating to dietary fat from the Block food screener (Block et al., 2000) described in Chapter 5.

**Stroop interference task.** Change in inhibitory control capacity was assessed using the computerised version of the Stroop interference task described in Chapter 5. This task was selected on the basis of neuroimaging studies that demonstrate activation of the same brain regions during SST and Stroop performance (Aron, Robbins, & Poldrack, 2004; Derrfuss, Brass, & Yves von Cramon, 2004). Additionally, several behavioural studies that have attempted to determine the degree of overlap between different inhibitory control tasks have concluded that there is not full independence between the measures, suggesting that they are indeed measuring similar constructs (Miyake et al., 2000; Verbruggen, Liefooghe, & Vandierendonck, 2004). Finally, the results of the study presented in Chapter 4 demonstrate a significant correlation between SST and Stroop performance and between these measures and saturated fat intake.

**Depletion task.** Participants were asked to write about what they had done over the weekend for five minutes with the instructions not to use two common letters, namely, a or n. Therefore, participants constantly were required to constantly inhibit the use of these letters and find alternative ways to express their thoughts. This task has been used in previous research to induce depletion, wherein participants who completed this task showed significant differences in a subsequent task requiring self-regulation compared to those who had not completed the task (Lewandowski, Ciarocco, Pettenato, & Stephan, 2012; Schmeichel, 2007). Participants also completed a four item questionnaire measuring their perceptions regarding the depletion task (Muraven & Slessareva, 2003), including how difficult and unpleasant (1 = extremely easy/pleasant – 7 = extremely difficult/unpleasant), and frustrating (1 = not at all...
frustrating – 5 = extremely frustrating), the depletion task had been for them. In addition, participants indicated how much effort the task required: “How much were you fighting against an urge while working on the task?” (1 = not at all – 5 = extremely), and written responses were reviewed to ensure that participants had completed the task correctly. See Appendix C for the task and related questionnaire. Depletion was calculated as the difference between Stroop interference before and after the depletion task, where a larger score indicated greater vulnerability to depletion. For example, if a participant had a Stroop interference score of 120ms before the depletion task, and a score of 220ms after the depletion task, their vulnerability to depletion score would be 100ms.

*Stop-signal task.* The current study utilised three versions of the SST with cues. All versions had the same task parameters as that described in Chapter 5, with the following exceptions. Stimuli consisted of eight colour pictures of both sweet and savoury unhealthy foods (e.g., potato chips, chocolate) and eight colour pictures of fruit and vegetables (e.g., apple, carrot) displayed on a white background and were approximately 450 by 400 pixels in size. The stimuli were comparable to those used in previous research on eating behaviour and impulsive responses (Veling et al., 2013b), and those represented in the Block food screener. See Appendix C for stimuli used in the SST.

For the *behaviour-specific inhibition* condition, the stop-signal was only presented after unhealthy food images, whereas for the *general inhibition* condition, the stop-signal was randomly presented either after a healthy or an unhealthy food image. For the *control* condition, participants performed the same task as the other conditions; however, no stop-signal were presented. If participants in either training condition inhibited their responses less than 50% of the time on inhibition trials this was an indication that they were not responding to the stop-signal correctly and thus that session was not included as a training
session. Similarly, if participants inhibited their responses more than 50% of the time, this was not counted as a training session and was excluded (Verbruggen et al., 2008).

Procedure

The study was conducted entirely online over 12 days. Participants were not explicitly told the aims of the study and were instead informed that they were to complete several reaction time tasks and report on their health behaviour. This was done in order to ensure that participants’ perceptions of the nature of the study did not influence their behaviour. Once participants had signed up to the study, and provided informed consent, they completed the pre-intervention measures in the following order: Stroop task, depletion task, Stroop task again, the dietary fat items from the Block food screener, and reported their height and weight. Finally, participants completed demographic measures and the questionnaire measuring their perceptions of the depletion task. On Days 2 – 11, participants completed one of three SST, depending upon the condition to which they had been randomly assigned. See Appendix D for examples of emails sent to participants. Finally, on Day 12 participants completed the same measures as Day 1, with the exception of height and demographic measures. Participants were fully debriefed as to the aims of the study. See Figure 7.1 for study flow diagram indicating the measures that were administered at each time-point and attrition.
Figure 7.1. Study flow diagram indicating measures at each time point. Scores on Stroop1 at pre- and post-intervention were compared to assess changes in inhibitory control.

Vulnerability to depletion = scores on Stroop2 – scores on Stroop 1.

Data analysis

In order to confirm that randomisation was successful the three experimental conditions were compared with respect to scores on pre-intervention measures of age, BMI, Stroop interference, vulnerability to depletion, and saturated fat intake using a one-way analysis of variance (ANOVA), while a chi-squared analysis was utilised to assess sex...
Results

**Randomisation check**

There were no significant differences in age, sex, BMI, saturated fat intake, Stroop interference, and vulnerability to, or perceptions of, depletion pre-intervention between conditions, all $p > .05$. Additionally, the number of training sessions completed across the training period did not differ between conditions, $p > .05$. On average, participants completed 8.47 ($SD = 2.66$) training sessions across the 10 day training period.
Attrition

Ten participants did not complete post-intervention measures (behaviour-specific inhibition: \( n = 3 \), general inhibition: \( n = 4 \), control: \( n = 3 \)). There were no differences in age, sex, BMI, saturated fat intake, Stroop interference or depletion, all \( p > .05 \), between those who dropped out and those who completed the study. Three participants dropped out of the study and seven did not sufficiently engage with all tasks.

Depletion

Participants’ performance on the Stroop task was significantly poorer following the depletion task, \( MD = 107.870, SE = 8.531; t(81) = 12.644, p < .001 \). Additionally, on average participants reported the task as difficult, \( M = 6.27, SD = 0.92 \), unpleasant, \( M = 5.12, SD = 1.29 \), frustrating, \( M = 3.61, SD = 1.24 \), and effortful, \( M = 3.35, SD = 1.07 \).

Training effects

Inhibitory control. There was a significant main effect of time indicating that all conditions improved on Stroop performance post-intervention, \( F(1, 69) = 4.635, p = .035 \), partial \( \eta^2 = .063 \). There was no main effect of condition, nor was the time by condition interaction effect significant, all \( p > .05 \). See Table 7.1 for pre- and post- intervention means and standard deviation of all test variables.
Table 7.1

*Means and Standard Deviations of All Outcome Variables for Each Condition Pre- and Post- Intervention*

<table>
<thead>
<tr>
<th></th>
<th>Pre-intervention</th>
<th></th>
<th>Post-intervention</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Behaviour-</td>
<td>General</td>
<td>Control</td>
<td>Behaviour-</td>
</tr>
<tr>
<td></td>
<td>specific</td>
<td></td>
<td></td>
<td>specific</td>
</tr>
<tr>
<td></td>
<td>( n = 29 )</td>
<td>( n = 25 )</td>
<td>( n = 28 )</td>
<td>( n = 26 )</td>
</tr>
<tr>
<td></td>
<td>( M )</td>
<td>( SD )</td>
<td>( M )</td>
<td>( SD )</td>
</tr>
<tr>
<td>Inhibitory control</td>
<td>159.06</td>
<td>114.26</td>
<td>151.79</td>
<td>104.05</td>
</tr>
<tr>
<td>Depletion</td>
<td>124.90</td>
<td>74.93</td>
<td>100.62</td>
<td>84.58</td>
</tr>
<tr>
<td>Saturated fat intake</td>
<td>23.16</td>
<td>7.49</td>
<td>24.34</td>
<td>7.04</td>
</tr>
<tr>
<td>BMI</td>
<td>22.21</td>
<td>2.04</td>
<td>22.78</td>
<td>2.43</td>
</tr>
</tbody>
</table>

*Note.* Inhibitory control = Stroop interference score (ms); Depletion = difference in Stroop interference scores pre- to post- depletion task (ms), Saturated fat intake = g/day calculated from dietary fat items of the Block food screener, BMI = body mass index.
**Vulnerability to depletion.** A comparison of pre- and post- intervention depletion scores revealed a significant main effect of time such that all conditions were less vulnerable to depletion post-intervention, $F(1, 69) = 15.097, p < .001$, partial $\eta^2 = .180$, which was qualified by a significant time by condition interaction effect, $F(2, 69) = 3.781, p = .028$, partial $\eta^2 = .099$; see Figure 7.2. A planned contrast examining the significant interaction revealed that both training conditions experienced less depletion post-intervention, compared to the control condition, $\psi = 55.146, F(1,69) = 6.377, p = .014$. Further, improvement in the behaviour-specific inhibition condition did not differ significantly from the general inhibition condition, $\psi = 23.953, F(1,69) = .8599, p = .357$. There was no main effect of condition on depletion, $p > .05$.

![Figure 7.2. Amount of depletion (difference in Stroop interference scores pre- to post-depletion task) experienced pre- and post- intervention for each condition. Error bars display standard error.](image-url)
**Saturated fat intake.** There was a trend effect of time on saturated fat intake such that all conditions tended to consume less saturated fat post-intervention, \( F(1, 69) = 3.700, p = .059, \text{partial eta}^2 = .051 \). There was no main effect of condition, nor was the time by condition interaction effect significant, all \( p > .05 \).

**BMI.** There was a significant main effect of time on BMI such that all conditions decreased in BMI post-depletion, \( F(1, 69) = 10.048, p = .002, \text{partial eta}^2 = .127 \), which was qualified by a significant time by condition interaction effect, \( F(2, 69) = 5.086, p = .009, \text{partial eta}^2 = .128 \), see Figure 7.3. A planned contrast examining the significant interaction revealed that BMI decreased in the behaviour-specific inhibition condition post-intervention, while BMI did not change in the general inhibition condition and the control, \( \psi = .354, F(1,69) = 10.171, p = .002 \). There was no main effect of condition, \( p > .05 \).

![Figure 7.3](image.png)

*Figure 7.3.* Body mass index pre- and post- intervention for each condition. Error bars display standard error.
Mediation analysis. As there were no changes in saturated fat intake the original mediation analysis was not conducted. However, the indirect effect of behaviour-specific inhibition training on BMI through vulnerability to depletion was tested. In order to conduct this analysis, the general inhibition condition was grouped with the control condition and compared to the behaviour-specific inhibition condition. Change in vulnerability to depletion and change in BMI variables were created by subtracting post-intervention scores from pre-intervention scores. The significance of the indirect effect was assessed using 95% confidence intervals, calculated using 5000 bootstrap re-samples (Hayes, 2012). The significance of this effect at the .05 level is supported if the 95% CI for the estimates of the mediation excludes zero. The indirect effect from behaviour-specific training, through change in vulnerability to depletion, to change in BMI was significant, $\beta = 0.071$, 95% CI: 0.01, 0.20, indicating that 7.1% of the variance in change in BMI was explained by the mediating effect of change in vulnerability to depletion on the type of training effect, see Figure 7.4 for standardised coefficients between all variables.

![Diagram](image)

Figure 7.4. Simple mediation model depicting the indirect effect of type of training on change in body mass index through change in vulnerability to depletion. Standardised beta coefficients are noted in the diagram, *$p < .05$, **$p < .01$
Discussion

This study represents one of the first to examine the mechanisms by which SST training produces changes in health behaviour. Specifically, the main questions of interest were whether online SST training can improve a specific eating behaviour, and further whether training influenced inhibitory control and/or vulnerability to depletion. Contrary to expectations, inhibitory control, as measured by performance on the Stroop interference task, improved in all conditions and did not appear to be influenced by the type of training. Despite this, a decrease in vulnerability to depletion was observed in the expected conditions, such that both the behaviour-specific inhibition and general inhibition training conditions demonstrated a decrease in depletion effects post-intervention. Contrary to predictions, behaviour-specific inhibition training did not improve eating behaviour as measured by self-reported eating behaviour. Although not an original aim of the study, training did, however, result in a decrease in BMI in the behaviour-specific condition, relative to general training and the control conditions, and changes in vulnerability to depletion mediated this effect.

There are several possible explanations for why training did not differentially influence inhibitory control capacity. Firstly, the Stroop task may not measure the same specific inhibitory control mechanism that SST training is influencing. Namely, the SST is a measure of response inhibition while the Stroop is suggested to be a measure of response inhibition and other constructs such as attention (Spierer et al., 2013). However, given that previous research has shown there to be overlap between the two tasks (Miyake et al., 2000; Verbruggen et al., 2004), it is unlikely to be the case that these measures are wholly independent. Additionally, the Stroop task used in the current study was the computerised version that requires participants to physically withhold their undesired responses, rather than refraining from verbalising. Therefore, it is likely that the computerised Stroop task does assess response inhibition.
Alternatively, SST training may have the potential to improve inhibitory control but did not in the current study due to methodological issues. The finding that all conditions demonstrated improved performance on the Stroop Task suggests a practice effect. While the Stroop procedure in the current study followed that commonly used in previous research (Cassiday, McNally, & Zeitlin, 1992; Formea & Burns, 1996; McNally, Riemann, & Kim, 1990), it may be that not enough practice trials were used. A sufficient number of practice trials is essential in order to acclimatise participants to the display and response characteristics of the task so that response times are based on interference rather than the novelty of the task (MacLeod, 2005).

While inhibitory control did not appear to improve as a function of the type of training, the present results indicated a significant change in vulnerability to depletion in the expected conditions. That is, both the behaviour-specific inhibition and general inhibition conditions demonstrated a decrease in depletion effects after training. Therefore, it appears that withholding a response to any stimuli is sufficient to improve elements of self-regulation including vulnerability to depletion. These results are similar to Muraven et al. (1999), who found that behavioural regulation techniques result in reduced depletion. Similarly, Oaten and Cheng (2007) found that after four months of engaging in financial monitoring participants were not only less vulnerable to depletion but also reported engaging in more health enhancing behaviours. In contrast, within the current study, while general SST training resulted in an improvement in vulnerability to depletion, this improvement did not transfer to eating behaviour. It may be that more intense training is required for improvements to translate across behavioural domains. Further research is required to determine the optimal intensity and length of training required to achieve such transfer effects.

SST training did not appear to alter self-reported eating behaviour. Previous research using the SST to influence eating behaviour has demonstrated differences between training...
and control conditions in the amount consumed in a pseudo taste test (Houben, 2011). The current results suggest that SST training may not be effective at changing eating behaviour outside the laboratory. Future research should compare both laboratory-based measures of eating behaviour and more ecologically valid measures to ascertain the external validity of SST training. Despite the null result for saturated fat intake, SST training did result in a small but significant decrease in BMI amongst the participants in the behaviour-specific condition. This may indicate that SST training did alter eating behaviour, but the measure used to assess this outcome was not sensitive enough to detect such changes. While food frequency questionnaires in general have been shown to be effective at assessing change in eating behaviour in intervention studies (Kristal, Beresford, & Lazovich, 1994), it is possible that this particular questionnaire was not appropriate as it did not take into account portion size, which is essential to the sensitivity of the instrument (Cade, Thompson, Burley, & Warm, 2002). Future research may benefit from the inclusion of eating measure that accounts for portion size.

Changes in vulnerability to depletion and BMI in the behaviour-specific condition indicate that improvement in vulnerability to depletion, when coupled with behaviour-specific training, may be a key mechanism by which SST training leads to better health outcomes. Indeed, a mediation analysis indicated that the indirect effect of type of training on change in BMI through change in vulnerability to depletion was significant. This suggests that while having a strong inhibitory control capacity is beneficial, it may be more beneficial to be able to continue to exercise this capacity after depletion (Muraven et al., 1999). Previous research has shown that attempting to suppress food-related thoughts leads to more food cravings and binge eating (Barnes & Tantleff-Dunn, 2010). Therefore, behaviour-specific inhibition training may have resulted in participants experiencing less depletion when suppressing food-related thoughts in day-to-day life, allowing them to continue
dedicating resources to the execution of their health goals. Future research, which examines whether training buffers the depleting effect of suppressing food-related thoughts, may further elucidate how training influences goal-directed behaviour.

**Implications**

The current study has several implications for both the design of behaviour change interventions and theoretical explanations for how SST training may influence behaviour. While these results need to be interpreted with caution, particularly as weight and height were self-reported, the finding that behaviour-specific inhibition training altered BMI is of particular interest as it indicates that ten sessions of an easily accessible task may lead to modest weight loss. In terms of theoretical advances, while it has been suggested that training needs to be behaviour-specific to improve health behaviour (Guerrieri et al., 2012; Jones & Field, 2012), this was the first study to examine whether SST training influences behaviour by improvement in inhibitory control or vulnerability to depletion. Interventions aimed at improving health behaviours therefore may benefit from including SST training in order to bolster against depletion effects experienced in everyday life. Further, changes in vulnerability to depletion in the general training condition indicate that non-contingent stop-signals have the potential to alter aspects of self-regulation, but are not sufficiently targeted to alter health behaviour.

**Strengths and limitations**

A particular strength of this study was the use of a pre- post- design to assess change in eating behaviour outcomes. This study also represents the first to assess the efficacy of SST training in the improvement of self-reported health behaviour, in order to determine whether training effects that have been previously observed in the laboratory translate into change in everyday behaviour. Finally, the intervention was executed in an online setting, and adherence was very high. Specifically, the study adherence rate was 96.3%, and the
intervention adherence rate was 91.5%, both markedly higher than rates reported for similar-length, online interventions (77% and 68%, respectively; Cugelman, Thelwall, & Dawes, 2011). Therefore, it is likely that the current intervention was engaging and suggests that implementing inhibitory control training in an online format is feasible.

There are several limitations to the current study that should be considered when interpreting the results. As mentioned above, the limited amount of practice trials in the Stroop task may have precluded the observation of changes in inhibitory control. As such, it is recommended that future research includes additional practice trials or uses an alternative measure of inhibitory control that is less sensitive to practice effects. Secondly, using a brief food frequency questionnaire may not have been sufficient to capture subtle changes in eating behaviour; therefore, future research may benefit from including more sensitive measures of eating behaviour. Furthermore, these results need to be replicated with objectively measured height and weight; for example, by conducting pre- and post- intervention measures in the laboratory so that the researcher can ensure accurate measurement. However, numerous studies have demonstrated that the correlation between self-report and objectively measured height and weight is very high ($r = .93 - .98$) amongst normal-weight participants (Larsen, Ouwens, Engels, Eisinga, & van Strien, 2008; Nawaz, Chan, Abdulrahman, Larson, & Katz, 2001; Niedhammer, Bugel, Bonenfant, Goldberg, & Leclerc, 2000).

Additionally, because there was not a control condition in which participants did not receive a depletion task, it is difficult to ascertain whether the vulnerability to depletion measure accurately assessed this construct. However, all participants performed poorer on the Stroop that followed the depletion task, suggesting that this task did in fact induce a depletion effect. Nevertheless, future research attempting to determine whether SST training can improve vulnerability to depletion should include a depletion control condition in order to test this assumption.
Conclusions

SST training appeared to decrease vulnerability to depletion, and when coupled with behaviour-specific inhibition training, this improvement transferred to positive weight outcomes. While these results appear promising, replication is required and several limitations of the current study need to be addressed. The following chapter presents a replication of this intervention, with the aim of addressing some of the aforementioned limitations.
Chapter 8 – Inhibitory control training and eating behaviour: Reliability and longevity of effects, and acceptability and feasibility of intervention

In the previous chapter, the results of an intervention designed to improve eating behaviour through SST training, and demonstrate the mechanism responsible for any changes in behaviour, were presented. It appeared that behaviour-specific training decreased participants’ vulnerability to depletion, which consequently influenced changes in BMI. However, these results need to be replicated in order to establish the reliability of the observed effects. Furthermore, no studies examining the influence of inhibitory control training on eating behaviour have included follow-up assessments in order to determine whether training gains persist over time. Therefore, the longevity of the previously observed effect needs to be tested in order to establish the usefulness of the intervention. Additionally, several hypothesised effects were not observed, namely, improvement in inhibitory control and eating behaviour. It is important to replicate the intervention with appropriate outcome variables in order to determine if the effect is truly not present, or if the null results were due to methodological limitations. Finally, the acceptability and feasibility of the intervention needs to be assessed in order to establish the usefulness of applying this intervention on a larger scale.

Thus, the results of a replication of the SST training intervention are reported in this chapter in order to establish the reliability and longevity of the previously observed training effects, address some of the methodological limitations present in the previous intervention, and assess the acceptability and feasibility of the intervention.

Reliability and longevity of effects

Given that the measurement of BMI in the previous intervention relied on self-report, it is possible that the observed change in BMI may have been subject to reporting bias. In
order to improve the accuracy of this measure, all measurements of weight in the current intervention were taken within the laboratory. Additionally, behavioural outcomes in the previous intervention were only measured immediately after the conclusion of the intervention; therefore, any changes that may have persisted beyond this time could not be observed. As it is important to assess the longevity of any training effects in order to establish the efficacy of the intervention, behaviour was also measured at a third time point: one week after post-intervention measures were administered.

As discussed in Chapter 7, methodological issues may have precluded the observation of expected training gains. Namely, the measure that was used to assess differences in eating behaviour may not have been sensitive enough to detect change in saturated fat intake. Therefore, an alternative self-report measure of eating behaviour, which has been validated in an intervention context, was used in the current study to measure eating behaviour. The National Cancer Institute (NCI) percentage energy from fat screener (Thompson et al., 2007) has been validated in intervention studies (Thompson et al., 2008; Williams et al., 2008), finding that the instrument was consistent at two time points with the gold-standard method of assessing dietary behaviour: the 24-hour food recall (Carter, Sharbaugh, & Stapell, 1981). While this measure does not specifically calculate saturated fat intake, it is preferable to other measures as it takes into account several factors that influence the consumption of dietary fat. Specifically, the formulae used to calculate percentage energy from fat takes into account age and sex in order to correct for portion size.

In addition to concerns regarding the measurement of eating behaviour, methodological issues may have prevented the observation of training-related changes in inhibitory control capacity in the previous intervention. Specifically, improvement in inhibitory control, as measured by changes in Stroop performance, may have been masked by practice effects on this task. As such, participants in the current intervention received a
substantial amount of practice trials on the Stroop task to ensure that responses on this task reflected inhibitory control capacity, rather than familiarity with the task.

**Acceptability and feasibility of the intervention**

An important element of intervention evaluation involves assessing the acceptability and feasibility of the intervention in order to determine whether full-scale implementation of the intervention is appropriate (Bartholomew, Parcel, Kok, & Gottlieb, 2001; Tones & Tilford, 2001). For example, factors such as relevance, credibility, and comprehension of the intervention, are thought to be prerequisites for successful behaviour change (Weinreich, 2010). Therefore, ratings of these factors, and several others, were taken at the conclusion of the current study in order to assess the acceptability and feasibility of the intervention.

**Aims & hypotheses**

The first aim of the current study was to assess the reliability and longevity of SST training effects by replicating the intervention reported in Chapter 7 (hereafter referred to as Intervention 1) with the inclusion of more accurate outcome measures and a third measurement time-point. The second aim of the study was to assess the acceptability and feasibility of SST training in order to determine the usefulness of implementing this intervention on a larger scale.

The hypothesised effects were identical to Intervention 1, with additional exploratory hypotheses regarding the maintenance of training effects. As no studies have examined whether the effects of SST training on eating behaviour persist over time, specific hypotheses were not made.
Method

Participants

Seventy-eight students and staff from a variety of disciplines at the University of Sydney (age = 22.97 years, $SD = 5.81$; BMI = 23.11, $SD = 2.56$; 61 females) were recruited to participate in a study in exchange for course credit or $20. The number of participants recruited was based on an a-priori power analysis conducted using G-Power 3 software (Faul et al., 2007), which indicated that a sample size of 57 would be sufficient to detect a small to medium (0.15) interaction effect between three conditions at three time points with a power of .80 and an alpha of .05. Inclusion criteria did not differ from Intervention 1. Participants were randomly allocated to one of three conditions: behaviour-specific inhibition ($n = 27$), general inhibition ($n = 26$), and control ($n = 25$) by clicking a URL, which randomly directed them to one of three pages. The university’s Human Research Ethics Committee approved the study and participants provided informed consent prior to participation. See Appendix A for ethics approval related to this study.

Materials and measures

BMI & Eating Behaviour. BMI was calculated from participants’ height and current weight. The researcher measured all participants at each time point on the same set of scales. Eating behaviour was operationalised as percentage daily fat intake as measured using the 17-item NCI percentage energy from fat screener (Thompson et al., 2007). Participants indicated how often they ate 15 food items (e.g., fruit, sausage or bacon, full fat cheese) on a 6-point scale ranging from 0 to 5: never (0); once per week (1); 1 to 2 times per week (2); 3 to 4 times per week (3); 5 to 6 times per week (4), once per day (5), 2 or more times per day (6). Additionally, participants were asked to indicate how often they used a reduced-fat butter or margarine, when they prepared foods with butter or margarine, on a 6-point scale ranging from 0 to 5: Didn’t use butter or margarine (0); almost never (1); about 1/4 of the time (2);
about 1/2 of the time (3); about 3/4 of the time (4); almost always or always (5). Finally, participants were asked to indicate whether they considered their diet to be low, medium or high in fat. See Appendix C for all items used in the screener. Percentage energy from fat was calculated using scoring algorithms that assign sex- and age- specific median portion sizes in grams to each item and then uses a regression model to estimate the expected intake given the screener responses.

**Stroop interference task.** Inhibitory control capacity was assessed using the same computerised version of the Stroop interference task as Intervention 1; however, the number of practice trials was increased from 20 to 50.

**Depletion task and Stop-signal task.** The depletion task and the three versions of the SST did not differ from Intervention 1.

**Acceptability and feasibility.** Nine items were used to assess the acceptability and feasibility of the intervention. Participants indicated how personally relevant, interesting, worthwhile, helpful/useful, easy to understand, easy to complete, credible, and annoying they felt the intervention to be, as well as whether they felt the intervention was too long, on a 5-point Likert Scale ranging from 1 to 5 (1 = strongly agree, 5 = strongly disagree). Finally, participants were given the opportunity to provide any additional feedback about the intervention.

**Procedure**

The study was conducted in the laboratory and online over 19 days. Once participants had signed up to the study and provided informed consent they completed the pre-intervention measures in the laboratory in the following order: Stroop task, depletion task, Stroop task again, the NCI percentage energy from fat screener, demographics, perceptions of the depletion task, and finally their height and weight were measured by the researcher. On Days 2 – 11, participants completed one of three versions of the SST online, depending upon
the condition to which they had been randomly assigned. On Day 12 participants returned to
the laboratory to complete the same measures as Day 1, with the exception of height and
demographic measures. Participants then returned to the laboratory for the follow-up testing
on Day 19, which included the same measures as those administered post-intervention, and
the acceptability and feasibility questionnaire. See Figure 8.1 for study flow diagram
indicating the measures at each measurement point and attrition.
Figure 8.1. Study flow diagram indicating measures at each time point.
Data analysis

Randomisation checks, drop-out analyses and depletion checks were performed as per Intervention 1. To assess the effect of training on Stroop performance and vulnerability to depletion two 3(time: pre-intervention, post-intervention, follow-up) by 3(condition: behaviour-specific inhibition, general inhibition, control) mixed ANOVAs were conducted. Overall effects were examined; however, focus was placed on time by condition interactions between two sets of levels of the within-participants factor (pre-intervention versus post-intervention, and pre-intervention versus follow-up). If a significant time by condition interaction was detected for either comparison, planned contrasts examining differences between the two training conditions and the control, and between the two training conditions themselves, were conducted. Similarly, to assess the effect of training on percentage energy from fat and BMI, two 3 x 3 mixed ANOVAs were conducted; with planned contrasts examining pre- to post- intervention, and pre-intervention to follow-up differences between the behaviour-specific inhibition condition and other conditions.

Acceptability and feasibility of the intervention. Descriptive statistics (mean and standard deviations) were used to describe the ratings obtained at the conclusion of the intervention. All items were scored from 1 to 5, with a higher score indicating greater agreement with target statements. In order to increase clarity in the reporting of statistics, each item mean is accompanied by the percentage of participants who agreed the with target statement. The “percent agreed” represents the proportion of participants who answered “strongly agree” or “agree” on the individual item. Pearson’s correlations were used to assess for potential relationships between participant’s pre-intervention characteristics and their acceptability and feasibility ratings of the intervention. Independent sample t-tests were conducted to explore differences in feasibility ratings between male and female participants.
Results

Randomisation check

There were no significant differences in age, sex, BMI, percentage energy from fat, Stroop interference, and vulnerability to, or perceptions of, depletion between conditions pre-intervention, all \( p > .05 \). Additionally, the number of SSTs performed across the training period did not differ between conditions, \( p > .05 \).

Attrition

Eight participants did not complete post-intervention and follow-up data (behaviour-specific inhibition: \( n = 3 \), general inhibition: \( n = 3 \), control: \( n = 2 \)). All drop-out occurred at the second time point (post-intervention). There were no differences in age, sex, BMI, percentage energy from fat, Stroop interference, or vulnerability to, or perceptions of, depletion, all \( p > .05 \), between those who dropped out and those who completed the study. Five participants dropped out of the study and three did not sufficiently engage with all tasks.

Depletion

Participants’ performance on the Stroop task was significantly poorer following the depletion task, \( MD = 109.527, SE = 15.323; t(77) = -7.148, p < .001 \). Additionally, on average participants reported the task as difficult, \( M = 6.28, SD = 0.79 \), unpleasant, \( M = 5.23, SD = 1.01 \), frustrating, \( M = 3.23, SD = 0.82 \), and effortful, \( M = 3.58, SD = 0.85 \).

Training effects

Means and standard deviation of all test variables at pre-intervention, post-intervention, and follow-up are displayed in Table 8.1.
Table 8.1

Means and Standard Deviations of All Outcome Variables for Each Condition at Pre-Intervention, Post-Intervention, and Follow-Up

<table>
<thead>
<tr>
<th></th>
<th>Pre-intervention</th>
<th>Post-intervention</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Behaviour-</td>
<td>Behaviour-</td>
<td>Behaviour-</td>
</tr>
<tr>
<td></td>
<td>specific</td>
<td>specific</td>
<td>specific</td>
</tr>
<tr>
<td></td>
<td>$n = 27$</td>
<td>$n = 24$</td>
<td>$n = 24$</td>
</tr>
<tr>
<td></td>
<td>$n = 26$</td>
<td>$n = 24$</td>
<td>$n = 24$</td>
</tr>
<tr>
<td></td>
<td>$n = 25$</td>
<td>$n = 23$</td>
<td>$n = 23$</td>
</tr>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
</tr>
<tr>
<td>Inhibitory control</td>
<td>138.86</td>
<td>99.62</td>
<td>32.10</td>
</tr>
<tr>
<td>Depletion</td>
<td>114.59</td>
<td>165.03</td>
<td>54.24</td>
</tr>
<tr>
<td>% Energy from fat</td>
<td>34.63</td>
<td>14.36</td>
<td>34.02</td>
</tr>
<tr>
<td>BMI</td>
<td>23.11</td>
<td>2.50</td>
<td>23.18</td>
</tr>
</tbody>
</table>

Note. Inhibitory control = Stroop interference score (ms); Depletion = difference in Stroop interference scores pre- to post-depletion task (ms), Percentage energy from fat calculated from NCI Percentage Energy from Fat Screener, BMI = body mass index.
Inhibitory control. There was a significant main effect of time indicating that averaged across all conditions, there were differences in Stroop performance according to the three time points, \( F(2, 134) = 22.687, \ p < .001, \ \text{partial eta}^2 = .253. \) Additionally, there was a significant time by condition interaction, indicating that the differences in Stroop performance according to time were not the same for each condition, \( F(4, 134) = 4.489, \ p = .002, \ \text{partial eta}^2 = .118. \) There was no main effect of condition, \( p > .05. \)

Examining the effect of time at two levels of the within-participants factor (from pre- to post- intervention) averaged across all conditions indicated that performance differed from pre- to post- intervention, \( F(1, 67) = 36.477, \ p < .001, \ \text{partial eta}^2 = .353. \) Similarly, examining the effect of time from pre-intervention to follow-up averaged across all conditions indicated that performance differed from pre-intervention to follow-up, \( F(1, 67) = 8.197, \ p = .006, \ \text{partial eta}^2 = .109. \) The effect of time from pre- to post- intervention was qualified by a significant time by condition interaction, indicating that the improvement in Stroop performance pre- to post- intervention differed according to condition, \( F(2, 67) = 6.004, \ p = .004, \ \text{partial eta}^2 = .152. \) However, the time by condition interaction from pre-intervention to follow-up was not significant, \( F(2, 67) = .086, \ p = .917, \ \text{partial eta}^2 = .003, \) indicating that there were no differences in performance from pre-intervention to follow-up according to condition.

A planned contrast examining the significant interaction effect revealed that both training conditions performed better on the Stroop post-intervention compared to the control condition, \( \psi = 92.492, \ F(1, 67) = 11.973, \ p = .001. \) However, this improvement was not maintained at follow-up as a planned contrast between pre-intervention and follow-up performance did not indicate significant differences between training conditions and the control, \( \psi = 9.105, \ F(1,67) = .163, \ p = .688. \) Additionally, improvement in performance demonstrated by the behaviour-specific condition from pre- to post- intervention did not
differ to that demonstrated by the general training condition, $\psi = 4.358$, $F(1,67) = .020$, $p = .887$, indicating that both forms of SST training improved inhibitory control as measured by the Stroop.

To summarise, it appeared that both the behaviour-specific and general training conditions improved in Stroop performance post-intervention; however, this improvement was not maintained at follow-up. The performance of all conditions across all time points is displayed in Figure 8.2.

\[\text{Figure 8.2. Inhibitory control performance (Stroop interference scores in ms) pre-intervention, post-intervention and at follow-up for each condition. Error bars display standard error.}\]

\textit{Vulnerability to depletion.} There was a significant main effect of time indicating that averaged across all conditions, there were differences in vulnerability to depletion according to the three time points, $F(2, 134) = 7.765$, $p = .001$, partial $\eta^2 = .104$. Additionally, there
was a significant time by condition interaction, indicating that the differences in vulnerability to depletion according to time were not the same for each condition, $F(4, 134) = 2.661, p = .035$, partial $\eta^2 = .074$. There was no main effect of condition, $p > .05$.

Examining the effect of time at two levels of the within-participants factor (from pre- to post- intervention) averaged across all conditions indicated that vulnerability to depletion differed from pre- to post- intervention, $F(1, 67) = 13.047, p = .001$, partial $\eta^2 = .163$.

Examining the effect of time from pre-intervention to follow-up averaged across all conditions indicated that vulnerability to depletion did not differ from pre-intervention to follow-up, $F(1, 67) = .037, p = .848$, partial $\eta^2 = .001$. The effect of time from pre- to post-intervention was qualified by a significant time by condition interaction, indicating that the decrease in vulnerability to depletion pre- to post- intervention differed according to condition, $F(2, 67) = 5.490, p = .006$, partial $\eta^2 = .141$. The time by condition interaction from pre-intervention to follow-up was not significant, $F(2, 67) = .103, p = .902$, partial $\eta^2 = .003$, indicating that there were no differences in vulnerability to depletion pre-intervention to follow-up according to condition.

A planned contrast examining the significant interaction revealed that both training conditions decreased in vulnerability to depletion post-intervention compared to the control condition, $\psi = 76.995, F(1, 67) = 8.347, p = .001$. However, this improvement was not maintained at follow-up as a planned contrast between pre-intervention and follow-up performance did not indicate significant differences between training conditions and the control, $\psi = 12.181, F(1, 67) = .195, p = .661$. Additionally, the decrease in vulnerability to depletion demonstrated by the behaviour-specific condition from pre- to post- intervention did not differ to that demonstrated by the general training condition, $\psi = .837, F(1, 67) = .001, p = .975$, indicating that both forms of SST training resulted in decreased vulnerability to depletion.
To summarise, it appeared that both the behaviour-specific and general training conditions demonstrated a decrease in vulnerability to depletion post-intervention; however, this improvement was not maintained at follow-up. The performance of all conditions across all time points is displayed in Figure 8.3.

*Figure 8.3. Amount of depletion (difference in Stroop interference scores pre- to post-depletion task in ms) experienced pre-intervention, post-intervention and at follow-up for each condition. Error bars display standard error.*

*Percentage energy from fat.* There were no effects of time, condition, nor were any time by condition interactions effects significant, all *p* > .05.

*BMI.* There was a significant effect of time on BMI indicating that averaged across all conditions, there tended to be differences in BMI according to the three time points, *F*(2, 136) = 3.105, *p* = .048, partial *η*² = .044. Examining the effect of time at two levels of the within-participants factor (from pre-intervention to follow-up) averaged across all conditions indicated that BMI differed from pre-intervention to follow-up, *F*(1, 68) = 5.000, *p* = .029,
partial $\eta^2 = .068$. However, there were no significant time by condition interactions overall or for each within-participants comparison, all $p > .05$. There was no main effect of condition, $p > .05$.

To summarise, while there appeared to be a decrease in BMI from pre-intervention to follow-up, this was not a function of type of training.

**Acceptability and feasibility of the intervention**

*Descriptive statistics.* The intervention was highly acceptable to participants with approximately 80 - 90% of the sample agreeing that the intervention as interesting, worthwhile, easy to understand, easy to complete, and personally relevant. Approximately 70 - 75% of participants agreed that the intervention was helpful/useful and credible. Up to 27% felt that the intervention was too long and approximately 21% of the sample found the intervention to be annoying. A summary of scores from the acceptability/feasibility questions completed at the conclusion of the intervention is displayed in Table 8.2.
Table 8.2
Sample Means and Proportion Agreed for Online SST training Feasibility and Acceptability Items

<table>
<thead>
<tr>
<th></th>
<th>% Agreed</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personally relevant</td>
<td>82%</td>
<td>4.102</td>
<td>.875</td>
</tr>
<tr>
<td>Interesting</td>
<td>80%</td>
<td>3.943</td>
<td>.899</td>
</tr>
<tr>
<td>Worthwhile</td>
<td>81%</td>
<td>4.059</td>
<td>.785</td>
</tr>
<tr>
<td>Helpful/useful</td>
<td>74%</td>
<td>3.501</td>
<td>.825</td>
</tr>
<tr>
<td>Easy to understand</td>
<td>90%</td>
<td>4.514</td>
<td>.756</td>
</tr>
<tr>
<td>Easy to complete</td>
<td>86%</td>
<td>4.257</td>
<td>.988</td>
</tr>
<tr>
<td>Credible</td>
<td>70%</td>
<td>3.355</td>
<td>1.123</td>
</tr>
<tr>
<td>Annoying</td>
<td>21%</td>
<td>2.629</td>
<td>1.092</td>
</tr>
<tr>
<td>Too long</td>
<td>27%</td>
<td>2.343</td>
<td>.796</td>
</tr>
</tbody>
</table>

Note. Responses ranged from strongly disagree (1) to strongly agree (5); % agreed = represents the proportion of participants who answered “strongly agree” or “agree” on the individual item.

Relationship between acceptability/feasibility and pre-intervention characteristics.

Older participants, $r = .342$, $p = .004$, and those who were more vulnerable to depletion pre-intervention $r = .248$, $p = .038$, were more likely to find the intervention to be too long. Additionally, males were more likely than women to rate the training as too long, $MD = 1.151$, $t(68) = -3.991$, $p < .001$, and annoying, $MD = -.697$, $t(68) = -2.189$, $p = .032$. There were no other significant relationships between pre-intervention measures and acceptability/feasibility items.

Qualitative feedback. Comments focused the ease or difficulty of completing the intervention with many providing reasons why they found it so. Generally, participants noted
that it was not difficult to complete the tasks. However, those who stated it was difficult stated that this was primarily due to having to remember to complete the task each day. Some participants stated that the task was mundane and required a fair amount of motivation to complete each day. Participants also commented on the length and whether or not they would continue the intervention for longer. Generally, participants indicated that the training period was an appropriate length. Some participants stated that they would continue for longer, but potentially only up to a fortnight. However, others suggested that a 7-day training period would be more manageable. Finally, all participants found the instructions for the SST task clear and easy to understand. A summary of the main themes that emerged from a qualitative review of participants’ comments is presented in Table 8.3.
Table 8.3  
*Representative Quotes for Acceptability and Feasibility of the Intervention*

<table>
<thead>
<tr>
<th>Difficulty</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“The daily tasks were simple and short so I had no trouble completing them daily”</td>
<td></td>
</tr>
<tr>
<td>“I personally had troubles remembering to complete each task daily because I was quite busy or simply forgot”</td>
<td></td>
</tr>
<tr>
<td>“The daily tasks were not difficult to complete. Though, it was difficult to do them at the same time each day with work commitments”</td>
<td></td>
</tr>
<tr>
<td>“It was annoying completing the task daily but maybe as I'm not overly disciplined”</td>
<td></td>
</tr>
<tr>
<td>“Daily tasks were not difficult but very mundane as it involves the same task with the same objects”</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“10 days was good enough, may have been easier to forget if it was for a longer period of time”</td>
<td></td>
</tr>
<tr>
<td>“I could have done it for more than 10 days, but maybe not longer than a fortnight”</td>
<td></td>
</tr>
<tr>
<td>“10 days was enough for me, it got a bit repetitive after a while”</td>
<td></td>
</tr>
<tr>
<td>“I would have been happy to have done it for more than 10 days as I found it fairly non-intrusive”</td>
<td></td>
</tr>
<tr>
<td>“7 days would be more manageable”</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Clarity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“It was helpful that a daily email was sent reminding me”</td>
<td></td>
</tr>
<tr>
<td>“Instructions were clear and easy to understand”</td>
<td></td>
</tr>
<tr>
<td>“I was confused at first as I was expecting feedback, but besides that everything was easy to use and complete”</td>
<td></td>
</tr>
</tbody>
</table>
Discussion

The aim of this study was to assess the reliability and longevity of inhibitory control training effects, and to evaluate the acceptability and feasibility of a 10-day online inhibitory control training intervention. The results suggested that both forms of training led to improvement in inhibitory control and vulnerability to depletion; however, this improvement did not lead to changes in eating behaviour or BMI. Therefore, the effect of training on vulnerability to depletion was replicated; however, the effect of behaviour-specific training on BMI was not. The results also suggested that these improvements in inhibitory control and vulnerability to depletion did not persist after the training period had ended, suggesting that inhibitory control training may only improve self-regulatory outcomes in the short-term. Finally, although the intervention may not be effective at changing health behaviour as measured in the current study, it appeared to be a highly accepted and feasible tool to improve self-regulatory outcomes.

Effect of training on self-regulatory outcomes and eating behaviour

The results indicated that both inhibitory control capacity, as measured by performance on the Stroop task, and vulnerability to depletion improved after both behaviour-specific inhibitory control training and general inhibitory control training. This suggests that repeatedly performing a task that requires inhibitory control results in improvements in this capacity and in the ability to exert this capacity after performing another task that requires self-regulation. This is in line with the strength model of self-regulation, which suggests that self-regulation relies on a limited pool of resources that can become depleted in the short-term, but strengthened over time with repeated acts of self-regulation (Baumeister, Vohs, et al., 2007). Additionally, these results reflect previous research that has used self-regulation training to improve self-regulatory outcomes. Specifically, Muraven (2010a) demonstrated that participants who were instructed to avoid
unhealthy foods for a two week period, or perform a handgrip task daily for two weeks, showed improved performance on an SST compared to control conditions that did not receive training. However, it appears that while modifying eating behaviour leads to improvement in inhibitory control, as measured by the SST, practicing an SST does not lead to changes in eating behaviour. It may be the case that exerting self-regulation in real-life situations requires more control and results in larger effects that are easily detectable on a reaction time measure, whereas practicing an abstract task may be a less intense form of training that does not translate to improvements in everyday behaviour.

The finding that inhibitory control training does not result in changes in eating behaviour is in contrast to numerous previous findings, which suggest that training results in improvement in eating behaviour (Houben, 2011; Houben & Jansen, 2011; Veling et al., 2011; Veling et al., 2013b). This may be explained by the measurement of eating behaviour. Previous research has not assessed change in eating behaviour, rather researchers have examined whether eating behaviour differs between those who received inhibitory control training and those who did not. It is possible that inhibitory control training may result in differences between trained and non-trained participants in an immediately administered laboratory task, but these observed differences do not translate into change in everyday behaviour. These findings lend support to the conclusions reached from the meta-analysis of inhibitory control training studies presented in Chapter 6 that suggested that training effects do not persist beyond the laboratory. Therefore, future research should include both methods of eating behaviour measurement in order to ascertain whether this is the case.

The finding that training resulted in improved self-regulation, but that this improvement did not lead to changes in health behaviour, does not appear to support a dual-systems approach to explaining eating behaviour. In this model, self-regulation is said to influence the role of both the reflective and impulsive systems by regulating the impulsive
system in order to facilitate the goals of the reflective system (see Figure 2.3; Hofmann, Friese, & Strack, 2009; Hofmann, Friese, et al., 2008). Therefore, improvement in self-regulatory ability is expected to result in change in health behaviour. This assumption was not supported by the current results. However, it may be the case that the reflective goals of the current sample were not strong enough to direct behaviour even after improvement in self-regulatory capacity. While participants were recruited on the basis of having the intention to eat healthily, this did not guarantee that intention strength was strong enough to influence behaviour.

Alternatively, it may be the case that self-regulatory capacity is not the only boundary condition that determines whether impulsive or reflective processes direct eating behaviour. Hofmann, Friese, et al. (2008) specify numerous boundary conditions other than self-regulation that may influence the relationship between the two systems and behaviour. For example, the habitualness of a behaviour, and whether stimuli are processed affectively or cognitively. Previous research has demonstrated that when behaviours are being performed habitually, reflective processes such as intention or goals do not influence eating behaviour (Allom & Mullan, 2012; Conner, Perugini, O'Gorman, Ayres, & Prestwich, 2007). It may be the case that unhealthy eating habits need to be interrupted before self-regulation training is useful in aiding the goals of the reflective system. Additionally, research has demonstrated that focusing on either affective or cognitive reactions to stimuli influences behaviour, such that an affective focus activates the impulsive system, which then guides behaviour (Scarabis, Florack, & Gosejohann, 2006). The utility of self-regulation training may differ according to an individual’s affective focus. Therefore, future research in which the aim is to improve eating behaviour may benefit from accounting for the role of habits and affective focus.
**Longevity of effects**

The observed changes in inhibitory control and vulnerability to depletion in the two training conditions were not maintained at follow-up. Although different training paradigms and behavioural outcomes were measured, these results are similar to that of Verbruggen et al. (2013), who did not find that inhibitory control training produced long-lasting effects. These results appear to indicate that inhibitory control training may only improve self-regulation outcomes in the short-term. While Baumeister and colleagues did not directly hypothesise about the maintenance of improvements in self-regulation (Baumeister, Vohs, et al., 2007; Hagger et al., 2010), the muscle metaphor commonly used to conceptualise self-regulation can be extended to account for these effects. Specifically, while exercise can strengthen a muscle, if exercise is not maintained strength will slowly decline. Similarly, it appears that if training is not continued, self-regulatory capacity may return to initial levels. Future research should attempt to replicate these effects in order to further knowledge regarding the nature of self-regulation.

**Acceptability and feasibility**

Overall, the intervention was rated by participants as highly acceptable. The majority of participants felt that the intervention was personally relevant, interesting, worthwhile, and easy to understand and complete. Additionally, the low rate of attrition from the intervention, and lack of differences on pre-intervention characteristics between those who dropped out or remained in the study, suggested that the intervention was sufficiently engaging and manageable. Specifically, the study adherence rate was 93.59% and intervention adherence rate was 96.15%. However, approximately 25% of participants felt the intervention was too long and annoying. These results are informative in terms of determining the length of future interventions that are aimed at improving inhibitory control and vulnerability to depletion. Qualitative results suggest that participants who felt the intervention was too long would have
preferred a 7-day training period. Additionally, older participants, males, and those who demonstrated more vulnerability to depletion pre-intervention, tended to rate the intervention as too long. Research aiming to improve inhibitory control within these populations may benefit from tailoring the length of the training to suit these individuals. However, it is not known whether these effects will be present when a shorter training period is used. Therefore, future research should pilot the intervention with varying lengths within these populations.

**Implications**

The current results have several implications for interventions designed to improve self-regulatory outcomes and eating behaviour. Namely, it appears that inhibitory control training does not result in changes in everyday eating behaviour. This suggests that the implementation of this technique alone as a means of improving eating behaviour may not be efficacious. However, more research in which a pre- post- design is employed to assess change in eating behaviour is needed to confirm these results. Further, future research may benefit from including both laboratory-based measures and self-report measures of eating behaviour in order to compare the validity of these measures and confirm whether previous significant results observed using laboratory measures are a true effect or an artefact of measurement. Additionally, these results contribute to theoretical explanations regarding the nature of self-regulation. While it has been established that elements of self-regulation can be improved through training (Muraven, 2010a), the current results suggest that the benefits of training are only maintained insofar as training is maintained. Furthermore, acceptability and feasibility data indicated that a 10-day online inhibitory control training intervention was suitable for the majority of participants, suggesting that the format of the current intervention may be a useful framework to employ in future research aiming to improve these elements of self-regulation or further explore whether inhibitory control training influences eating behaviour. Moreover, these results indicated for whom this format was not suitable and
suggested that particular sub-samples of participants may benefit from a shorter training period. Future research in which the aim is to train self-regulatory outcomes should take these findings into consideration in order to develop interventions that are suitable to the target audience.

**Strengths and limitations**

A particular strength of this study was the inclusion of a third time-point in order to assess the longevity of any observed training effects, and the inclusion of acceptability and feasibility assessment. However, there are several limitations to the current study that should be considered when interpreting the results. Firstly, the finding that inhibitory control training did not improve eating behaviour may be due to the measurement of eating behaviour. While a questionnaire that was validated for intervention studies was used, it may be the case that this measure is not suitable to detect subtle changes in eating behaviour. However, if inhibitory control training only produces small effects, which are not practically significant, this technique alone may not be a viable method of behaviour change. Secondly, previous research has shown that individual difference variables such as dietary restraint (Houben & Jansen, 2011; Veling et al., 2011), and homeostatic variables such as previous food intake and hunger (Loeber, Grosshans, Herpertz, Kiefer, & Herpertz, 2013), influence food cue processing. Future research may benefit from including and controlling for these variables to determine whether training-related outcomes differ amongst these sub-samples. Thirdly, while the stimulus set used in both interventions reported in this thesis reflected that used in other inhibitory control training and eating behaviour interventions (Veling et al., 2013b), it was not validated for the respective samples. Future research should assess participants’ perceptions of the healthiness and palatability of food items in order to ensure that the selected stimuli are perceived as healthy or unhealthy. Further, piloting stimuli will ensure that the selected unhealthy foods are considered palatable by the target sample. If participants
are not tempted to consume the selected unhealthy foods, inhibitory control training may not be relevant.

Conclusions

This chapter presented the results of a replication of an inhibitory control training study in which the aim was to improve eating behaviour and demonstrate the mechanism by which this improvement occurs. This replication was carried out to not only to ensure the reliability of the previously found training effects, but to also test the longevity of the effects and improve the measurement of outcome variables. The results of this study did not replicate previous findings, such that inhibitory control training in this intervention did not appear to influence health outcomes. However, the results indicated that inhibitory control training does appear to improve inhibitory control, as measured by a related task, and the construct of vulnerability to depletion, but these effects do not appear to persist after training has ceased.
Chapter 9: General Discussion

The overall aim of the work presented in this thesis was to examine the role and trainability of specific elements of self-regulation in the context of healthy eating. This aim was achieved by taking a multi-methods approach, which enabled a qualitative and quantitative examination of the influence of executive function on the prediction and modification of eating behaviour. The design and theoretical basis of the studies presented in this thesis, were based on reviews of theoretical models and previous findings discussed in the early chapters of this thesis. The middle chapters of this thesis presented results of three studies that provided evidence for the role of executive function in eating behaviour and specifically identified inhibitory control as an influential factor in the regulation of eating behaviour. The implementation and evaluation of an inhibitory control training intervention is described in two studies reported in Chapter 7 and Chapter 8. In this chapter, an overview of the major research findings from the present work is presented. It begins with a discussion of results from each of the stages of the research and concludes with a discussion of the strengths and limitations of the research, and the implications for future work.

Summary of research findings

As described in Chapter 1, the research presented in this thesis was conducted in five stages (see Figure 9.1).
Stage 1. Theories of health behaviour: where does self-regulation fit in?
Overview of current theories used to explain and predict eating behaviour
Synthesis of research relating to executive function and eating behaviour

Stage 2. Exploring implicit theories of self-regulation and eating behaviour
Qualitative analysis of the experiences and perceptions of healthy eaters

Stage 3. Prediction of eating behaviour using executive function constructs
Predictive study that examined the relationship between two categories of executive function and eating behaviour

Stage 4. Determining the efficacy of current executive function training interventions
Meta-analysis assessing the effect of inhibitory control training on behaviour regulation

Stage 5. Inhibitory control training and eating behaviour change
Intervention designed and implemented with the aim of improving eating behaviour and determining the mechanism responsible for change
Replication and extension of intervention in order to test reliability and longevity of effects and acceptability and feasibility of the intervention

Figure 9.1. Outline of research conducted in this thesis.
Stage 1: Theories of health behaviour: where does self-regulation fit in?

The rationale for this work is outlined in Chapter 2. As discussed in that chapter, healthy eating behaviours such as minimising the intake of dietary fats and consuming the appropriate amount of fruit and vegetables reduces the risk of numerous negative health consequences, including obesity and many other non-communicable diseases that result from this condition (Harvey et al., 2011; Hubert et al., 1983; Strazzullo et al., 2010). The rates of adherence to healthy eating guidelines, which specify the appropriate amount of consumption of these food conditions, indicate that many individuals engage in unhealthy eating behaviours and are thus at a greater risk of developing obesity (Australian Institute of Health and Welfare, 2012; McLennan & Podger, 1998). These findings indicated the need to examine the factors that underlie eating behaviour. As discussed, current conceptualisations of the determinants of eating behaviours (Ajzen, 1991), which focus on the role of reflective processes such as intention, may not adequately capture the full nature of eating behaviour (Sniehotta et al., 2014). Self-regulation was proposed as an influential determinant of eating behaviour and was evaluated in the context of three models used to predict and explain behaviour: the TPB (Ajzen, 1991), TST (Hall & Fong, 2007), and the reflective-impulsive model or dual-systems approach (Hofmann, Friese, et al., 2008; Strack & Deutsch, 2004). It was concluded that a dual-systems approach in which the role of both reflective and impulsive processes are considered to influence behaviour, and self-regulation is hypothesised to determine the influence of such processes, offers a more complete account of how health behaviours are executed.

In Chapter 3, a comprehensive review of the processes underlying self-regulation, namely executive functions, was reported and research examining the relationship between particular elements of executive function and eating behaviour was discussed. Three categories of executive functions and the measurement of these processes were discussed:
shifting, inhibitory control, and updating (Miyake et al., 2000). After examining evidence regarding the relationship between shifting and eating behaviour (Fitzpatrick et al., 2013; Roberts, Tchanturia, et al., 2007), it was concluded that this category of executive function may not be a useful target for the prediction and modification of eating behaviour within normal-weight adults. However, regarding inhibitory control and updating, the research reviewed appeared to indicate a clear connection between these facets of executive function and the eating behaviour of normal-weight participants. Specifically, poorer performance on measures of inhibitory control or updating relates to difficulties in the regulation of eating behaviour (Friese et al., 2008; Hall, 2012; Hofmann, Gschwendner, et al., 2008; Nederkoorn et al., 2010). It was concluded that these two elements of executive function warrant further exploration in the context of healthy eating behaviour.

**Stage 2: Exploring implicit theories of self-regulation and eating behaviour**

In order to begin to address the aim of comprehensively examining the role of self-regulation in the context of eating behaviour, a qualitative approach was firstly adopted. In Chapter 4, the results of a series of focus groups, in which the perceptions and experiences of successful healthy eaters were explored, was presented in order to determine the factors and processes that these individuals saw as influential in the regulation of eating behaviour. The results revealed that healthy eaters encountered barriers to healthy eating; however, healthy eaters engaged in strategies that lessened the impact of these barriers, such as constantly maintaining focus on healthy eating goals, and resisting the tendency to respond to cues to eat unhealthy. The specific strategies that were described were synthesised with previous findings regarding eating behaviour and executive function, which suggested that superior inhibitory control and updating may be underlying healthy eating behaviour. The results also offered insight into how these individuals conceptualised the ability to self-regulate supporting previous findings regarding the effect of viewing will-power as a limited or a non-
limited resource (Job et al., 2010), and highlighting how successful self-regulation may lead to healthy habits.

**Stage 3: Prediction of eating behaviour using executive function constructs**

In Chapter 5 the results of a study, in which the qualitative findings of Chapter 4 were tested quantitatively, were presented. That is, individual differences in inhibitory control and updating were used to predict two distinct eating behaviours: saturated fat intake and fruit and vegetable consumption. Of particular interest was whether these elements of executive function would be differentially related to particular kinds of healthy eating behaviour. The results revealed a double dissociation between elements of executive function and types of eating behaviour, such that inhibitory control was shown to be important for behaviours that require the stopping of a response (i.e., limiting the intake of foods high in saturated fat), while updating was shown to be important for carrying out behaviours that require the initiation of a response (i.e., fruit and vegetable consumption). The results supported the distinction put forth by de Ridder et al. (2011) between different types of self-regulation and indicated that the relevance of these types of self-regulation may depend upon the nature of the behaviour in question.

**Stage 4: Determining the efficacy of current executive function training interventions**

A meta-analysis in which the aim was to determine the effectiveness of inhibitory control training interventions designed to improve behaviour regulation was reported in Chapter 6. Additionally, the second aim was to resolve any inconsistencies in the effect sizes and determine the most efficacious format of training by examining several potential moderators. The results provided evidence that inhibitory control training led to differences in behavioural outcomes including eating behaviour. Further, it was revealed that inhibitory control tasks needed to be tailored to the target behaviour in order to be successful. The results also highlighted several limitations within the inhibitory control training and eating
behaviour literature that needed to be addressed in future studies. Namely, there was a need to test whether training resulted in change in behaviour, whether these effects translated into everyday behaviour, and the longevity of these effects. Finally, within the eating behaviour literature, limited attention was directed toward determining mechanisms responsible for differences in behaviour. As such, this concern also needed to be addressed.

Stage 5: Inhibitory control training and eating behaviour change: Addressing remaining questions

The results of an intervention designed to improve self-reported eating behaviour through inhibitory control training, and assess the underlying mechanisms responsible for change in eating behaviour, were reported in Chapter 7. Based on previous conceptualisations of self-regulation (Muraven et al., 1999; Vohs & Heatherton, 2000), and dual-systems approaches to explaining behaviour (Friese et al., 2011; Hofmann, Friese, et al., 2008), two potential mechanisms were tested: inhibitory control capacity and vulnerability to depletion. It appeared that behaviour-specific training resulted in a decrease in BMI, but not saturated fat intake, and this change was mediated by change in vulnerability to depletion. General inhibitory control training also resulted in a decrease in vulnerability to depletion but, as expected, this did not lead to differences in eating behaviour. Contrary to expectations, inhibitory control capacity was not influenced by training. While the results appeared promising, replication was required and several limitations needed to be addressed.

Finally, the results of a second inhibitory control training intervention designed to establish the reliability and longevity of the previously observed effects, and determine if null results found in the first intervention were the product of methodological limitations, were reported in Chapter 8. The acceptability and feasibility of the intervention was also assessed in order to establish the usefulness of applying the intervention on a larger scale. Both inhibitory control capacity and vulnerability to depletion improved after both forms of
training; however, the effect of behaviour-specific training on BMI was not replicated and there were no differences in eating behaviour. The results also suggested that the observed improvements in self-regulatory outcomes did not persist beyond the training period. Finally, although the intervention may not have been effective at changing health behaviour, it appeared to be a highly acceptable and feasible tool to improve self-regulatory outcomes. Overall, it appeared that while inhibitory control training may improve self-regulatory outcomes in the short-term, these improvements do not translate into change in everyday eating behaviour.

**Implications and directions for future work**

The research presented in this thesis has numerous implications for theoretical explanations of the role of elements of self-regulation in the performance of eating behaviours, and practical implications for interventions designed to improve self-regulation and eating behaviour. Additionally, this work presents a number of important lines of inquiry for future research. Such research should build on the results of the present work and, where possible, should seek to incorporate the strength of the current approach. Some of the major avenues for future are briefly outlined in this section.

Broadly, the results of this work indicate that specific elements of self-regulation; namely, inhibitory control and updating ability, are predictive of two behaviours crucial to achieving the goal of healthy eating: limiting fat intake and consuming fruit and vegetables. While the work in this thesis primarily focused on inhibitory control and fat intake, there is scope to further explore the relationship between updating and fruit and vegetable consumption. As described in Chapter 6, limited research has focused on determining whether training on tasks related to updating ability results in positive health outcomes. Further, while one study examined whether such training could reduce a health risk behaviour (i.e., alcohol consumption Houben, Wiers, et al., 2011), no studies have attempted to improve
a health enhancing behaviour (e.g., fruit and vegetable consumption) through training. Therefore, it is worthwhile examining whether processes, which have been shown to be important for the performance of health enhancing behaviours, can be modified to improve engagement in these behaviours.

The work in this thesis provides a step forward in the understanding of inhibitory control training and health behaviour and has several implications for the direction of future inquiry. Firstly, it is recommended that future research employ a pre- to post- design in order to further explore whether inhibitory control training can produce change in eating behaviour. This endeavour may be difficult given the limitations of currently available measures of eating behaviour (Thompson & Subar, 2013). Food screeners and questionnaires that require individuals to recall eating behaviour over the course of the training period, and at any follow-up measurement points, may not be sensitive enough to detect the changes in eating behaviour that inhibitory control training promotes. While laboratory-based measures such as pseudo taste tests may be more sensitive to differences in behaviour, this instrument has limited generalisability (Smyth et al., 2001), and administering a pseudo taste test at two time points may reveal the nature of the study. Future research may benefit from employing 24h food recalls that have been shown to accurately reflect eating behaviour in intervention studies (Carter et al., 1981). Alternatively, rather than attempting to calculate grams of fat consumed from responses on a questionnaire, it may be worthwhile assessing broader eating behaviours such as self-selected portion size (van Koningsbruggen et al., 2013), or food choice (Veling et al., 2013b).

The results of this research also indicated that there is scope to explore the appropriate intensity of inhibitory control training. Specifically, the results of the intervention presented in Chapter 8 revealed that training produced changes in inhibitory control and vulnerability to depletion. While these changes did not result in improvement in eating behaviour, it is
possible that a higher dosage of training may. The SST that participants performed daily for
ten days involved 192 trials and was approximately six minutes long. The qualitative results
presented in Chapter 8 revealed that there was variability in the acceptability of the length of
training. Some participants indicated that they would have continued the training while others
indicated that a shorter training period with longer sessions would have been more suitable.
The meta-analysis presented in Chapter 5 did not indicate a significant effect of number of
trials on behavioural outcomes. However, as noted, there were many inconsistencies between
training paradigms that may have precluded the observation of differences in outcomes as a
function of length of training. Therefore, future studies should systematically vary the
number of trials and length of training period in order to ascertain whether intensity of
training influences health outcomes and if so, to determine the optimal length of training for
specific individuals.

Alternatively, research in which the aim is to further explore the potential of executive
function training to improve health behaviour should consider training multiple elements of
executive function concurrently. It may be the case that training response inhibition is too
narrow to result in behaviour change in everyday life. While particular facets may be more
strongly related to certain behaviours, the execution of health behaviour does not rely solely
on one facet of executive function (Baumeister, Schmeichel, et al., 2007; Hofmann et al.,
2012). Miyake et al. (2000) demonstrated that complex tasks demand more than one element
of executive function. Namely, random number generation draws on multiple executive
functions in that it requires inhibitory control in order to suppress habitual responses,
updating ability to monitor previous responses, and finally, Baddeley (1998) suggested that
the task also requires shifting of retrieval strategies. Although potentially difficult, it may be
worthwhile developing and implementing an intervention that trains numerous elements of
executive function by creating a complex executive function task or by using a combination of different tasks.

Additionally, given that training appeared to produce change in self-regulatory outcomes, it may be worthwhile implementing inhibitory control training as an adjunct to current interventions designed to improve eating behaviour. As discussed in Chapter 8, it is possible that the individuals in this intervention did not have strong enough intentions to guide behaviour even after the influence of the reflective system was strengthened by improvements in self-regulation. It may be worthwhile combining inhibitory control training with other behaviour change techniques that target the reflective system such as implementation intentions. However, a recent study by van Koningsbruggen et al. (2013), in which the aim was to modify eating behaviour by administering two behaviour change techniques, did not demonstrate additive effects of combining both implementation intentions and SST training. Therefore, combining these particular intervention strategies may not be a suitable approach; however, future research may wish to explore whether other behaviour change techniques (Michie et al., 2011), in combination with inhibitory control training, are more efficacious.

**Strengths and limitations of this research**

A strength of this research was the overall approach that was taken to meet the aim of examining the role and modifiability of executive function in the context of healthy eating. The work followed a progression from qualitatively establishing the factors that are influential in the performance of healthy eating, to confirming the role of these factors in the prediction of two eating behaviours, to reviewing current knowledge of inhibitory control training in order to inform the research aims and design of an intervention that was implemented, evaluated and replicated.
There are limitations to the current body of work that also must be acknowledged. Firstly, while a dual-systems approach was used to inform design of experiments and interpretation of results, the role of the impulsive system was not a focus of this research. While the aim was primarily to improve self-regulation, this work would have benefited from the inclusion of implicit measures designed to assess impulsive processes (e.g., the implicit association task; Greenwald et al., 1998). Future research should account for the role of the impulsive system by measuring implicit attitudes towards unhealthy and healthy foods in order to determine the strength of influence of these factors on eating behaviour and whether inhibitory control training influences these processes. Namely, it has been suggested that pairing stop-signals or a no-go response with particular stimuli results in devaluation of that stimuli, which in turn results in behaviour change (Houben, Nederkoorn, et al., 2011; van Koningsbruggen et al., 2013; Veling et al., 2013a).

**Conclusions**

Overall, the work presented in this thesis represents a comprehensive examination of the role and trainability of executive function in a healthy eating context. While inhibitory control training did not appear to influence health behaviour, the systematic examination of this technique is a step toward understanding the efficacy of such strategies to change everyday health behaviour. The results of the work presented in this thesis also provide many avenues for future enquiry regarding self-regulation in general, and the improvement of health behaviour through executive function training.
References


Grodstein, F. (2012). Dietary fat types and 4-year cognitive change in community-
dwelling older women. *Annals of Neurology, 72*(1), 124-134.
activity after training of working memory. *Nature Neuroscience, 7*(1), 75-79.
Psiquiatria, 58*(3B), 826-829.
neural basis of executive function in working memory: an fMRI study based on
Theta and gamma oscillations predict encoding and retrieval of declarative memory.
*The Journal of Neuroscience, 26*(28), 7523-7531.
processes by which past behavior predicts future behavior. *Psychological Bulletin,
124*(1), 54-74.
and physical activity affect the body mass index of Chinese adults. *International
Journal of Obesity and Related Metabolic Disorders, 22*(5), 424-431.
Papies, E. K., & Hamstra, P. (2010). Goal priming and eating behavior: Enhancing self-
regulatory success in restrained eating. *Personality and Social Psychology Bulletin,
34*(9), 1290-1300.


Appendices

Appendix A: Ethics approvals for research conducting in this thesis

1. Ethics approval for focus group study presented in Chapter 4
2. Ethics approval to conduct predictive study presented in Chapter 5, and two intervention studies conducted in Chapter 7 and Chapter 8
3. Ethics modification approval to use stop-signal task and depletion task in studies presented in Chapter 7 and 8
4. Ethics modification approval to include a third measurement point and the NCI Percentage Energy from Fat Screener in study presented in Chapter 8

Appendix B: Topic Guide for focus group study presented in Chapter 4

Appendix C: Questionnaires and materials

1. Dutch Eating Behaviour Questionnaire
2. Block Food Screener
3. Depletion Task
4. Stimuli used in stop-signal task
5. NCI Percentage Energy from Fat Screener

Appendix D: Emails sent to participants for intervention studies presented in Chapter 7 and 8

1. Emails sent to participants on Day 1 of training
2. Emails sent to participants on Days 2-10 of training

Appendix E: Publications relating to this thesis

Appendix A: Ethics approvals for research conducting in this thesis

1. Ethics approval for focus group study presented in Chapter 4
11. Adding New Staff Member / Student / Research Assistant

If YES, provide the following (If more than one, please copy this table and attach below)

<table>
<thead>
<tr>
<th>Name:</th>
<th>Vanessa Allom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title: (e.g: Mr, Ms, Dr, Associate Professor)</td>
<td>Ms</td>
</tr>
<tr>
<td>Faculty:</td>
<td>Science</td>
</tr>
<tr>
<td>Discipline/Department:</td>
<td>Psychology</td>
</tr>
<tr>
<td>Address:</td>
<td>School of Psychology (A18)</td>
</tr>
<tr>
<td></td>
<td>The University of Sydney NSW 2006</td>
</tr>
<tr>
<td>Telephone Number:</td>
<td>+61 2 90367267</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:vall2756@uni.sydney.edu.au">vall2756@uni.sydney.edu.au</a></td>
</tr>
<tr>
<td>Position (ie lecturer, PhD student):</td>
<td>PhD student</td>
</tr>
<tr>
<td>Qualifications (if PhD indicate field of study):</td>
<td>Bachelor of Psychology (Hons)</td>
</tr>
<tr>
<td>Role in the project:</td>
<td>Researcher</td>
</tr>
</tbody>
</table>

Has the new staff member received a copy of the approved application (including any current conditions of approval and any existing approved amendments)? ☑ Yes ☐ No

Signature of new staff member / student / research assistant. By signing this form, the new staff member / student / research assistant (a) acknowledges receiving and reading a copy of the approved application, and (b) agrees to be bound by the approved application (including any current conditions of approval and any existing approved amendments)

Signature: Vanessa Allom

Print Name: Vanessa Allom

Date: 12/07/2011

SECTION B - ADDITION OF TITLE TO HREC DATABASE

12. Please provide details of the additional title to be added to the HREC Database

Title:

Granting Body:

SECTION C - EXTENSION OF HREC APPROVAL

13. What is the proposed new finishing date?

14. Please provide a reason for the requested time extension

---

1 Such an addition is not effective until HREC approval is obtained
2. Ethics approval to conduct three studies presented in Chapter 5, 7 and 8
**Condition/s of Approval**

- Continuing compliance with the National Statement on Ethical Conduct in Research Involving Humans.
- Provision of an annual report on this research to the Human Research Ethics Committee from the approval date and at the completion of the study. Failure to submit reports will result in withdrawal of ethics approval for the project.
- All serious and unexpected adverse events should be reported to the HREC within 72 hours.
- All unforeseen events that might affect continued ethical acceptability of the project should be reported to the HREC as soon as possible.
- Any changes to the protocol including changes to research personnel must be approved by the HREC by submitting a Modification Form before the research project can proceed.

**Chief Investigator / Supervisor’s responsibilities:**

1. You must retain copies of all signed Consent Forms and provide these to the HREC on request.
2. It is your responsibility to provide a copy of this letter to any internal/external granting agencies if requested.

Please do not hesitate to contact Research Integrity (Human Ethics) should you require further information or clarification.

Yours sincerely

\[Signature\]

Dr Margaret Faedo  
Manager, Human Ethics  
On behalf of the HREC

cc: Vanessa Allom  vall2758@uni.sydney.edu.au

---

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) National Statement on Ethical Conduct in Human Research (2007), NHMRC and Universities Australia Australian Code for the Responsible Conduct of Research (2007) and the CPMP/ICH Note for Guidance on Good Clinical Practice.
3. Ethics modification approval to use stop-signal task and depletion task for studies presented in Chapter 7 and 8

Kala Retnam

From: Kala Retnam on behalf of Human Ethics
Sent: Friday, 17 February 2012 1:55 PM
To: Barbara Mullan
Cc: "val82768@uni.sydney.edu.au"
Subject: Modification Approval Deferred - 14157
Attachments: 4.4 14157 Mullan.pdf

Dear Dr Mullan

Title: The role of self-regulation in dietary behaviour
Protocol No: 14157

Your request for modification (see attached) was considered by the Executive Committee of the Human Research Ethics Committee on 15 February 2012.

The HREC Executive Committee seeks clarification of the following to be reviewed by the HREC Executive Committee:

- Please provide justification for the addition of the five cognitive tasks.

The Executive Committee will give further executive consideration when the above concerns have been addressed.

Submission deadline and Date of Meeting are available on the Human Ethics website at: http://sydney.edu.au/research_support/ethics/human/deadlines under “Submission of modifications and recognition of external approval”.

Please do not hesitate to contact the Research Integrity (Human Ethics) should you require further information or clarification.

Yours Sincerely

Human Research Ethics Executive Committee
The University of Sydney
4. Ethics modification approval to include a third measurement point and the NCI Percentage Energy from Fat Screener for study presented in Chapter 8

Research Integrity
Human Research Ethics Committee

Wednesday, 11 September 2013

Dr Barbara Mullan
Psychology, Faculty of Science
Email: barbara.mullan@sydney.edu.au

Dear Dr Barbara Mullan,

Your request to modify the above project submitted on 20th August 2013 was considered by the Executive of the Human Research Ethics Committee at its meeting on 4th September 2013.

The Committee had no ethical objections to the modification/s and has approved the project to proceed.

Details of the approval are as follows:

Project No.: 2012/1947
Project Title: The role of self-regulation in dietary behaviour

Approved Documents:

<table>
<thead>
<tr>
<th>Date Uploaded</th>
<th>Type</th>
<th>Document Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>14/08/2013</td>
<td>Questionnaires/Surveys</td>
<td>Appendix A - Percentage Energy from Fat</td>
</tr>
<tr>
<td>20/08/2013</td>
<td>Participant Info Statement</td>
<td>Appendix C - Updated Participant Information Statement</td>
</tr>
<tr>
<td>20/08/2013</td>
<td>Advertisements/Flyer</td>
<td>Appendix D - Updated SONA Advertisement</td>
</tr>
</tbody>
</table>

Please do not hesitate to contact Research Integrity (Human Ethics) should you require further information or clarification.

Yours sincerely

S. J. Assinder
Chair
Human Research Ethics Committee

This HREC is constituted and operates in accordance with the National Health and Medical Research Council’s (NHMRC) National Statement on Ethical Conduct in Human Research (2007), NHMRC and Universities Australia Australian Code for the Responsible Conduct of Research (2007) and the CPMP/ICH Note for Guidance or Good Clinical Practice.
Appendix B: Topic Guide for focus group study presented in Chapter 4

Tell us your name and favourite food

Describe a healthy diet

Describe a healthy weight

Describe your eating behaviour

We specified that we were interested in the thoughts and experiences of people who are able to maintain healthy eating behaviour:

- Describe particular successes or struggles you’ve encountered while trying to eat healthily
  - Prompt: maintaining focus on healthy eating goal, self-control

- What enables the maintenance of your healthy eating behaviour?
  - Prompt: Routine, internal states, particular situations

- What impedes the maintenance of your healthy eating behaviour?
  - Prompt: things in the environment, e.g. fast food options, smell of yummy food, internal things such as sleep, past behaviour, habit

- Generally, what do think makes someone able to stick to a healthy diet?
  - Prompt: characteristics of the person, things in their life

What would you change in your life to make it easier to stick to a healthy diet?

We are interested in how healthy eaters differ from unhealthy eaters, what advice do you have for us?
Appendix C: Questionnaires and materials

1. Dutch Eating Behaviour Questionnaire

All responses are on a 5-point Likert Scale anchored by never (1) ---------- very often (5)

Restrained Eating

1. Over the last week, if you have/were to put on weight, did you/would you eat less than you usually do?
2. Over the last week, did you try to eat less at mealtimes than you would have liked to eat?
3. Over the last week, how often did you refuse food or drink offered to you because you were concerned about your weight?
4. Over the last week, did you watch exactly what you ate?
5. Over the last week, did you deliberately eat foods that are slimming?
6. Over the last week, when you ate too much, do you eat less than usual the following days?
7. Over the last week, did you deliberately eat less in order not to become heavier?
8. Over the last week, how often did you try not to eat between meals because you were watching your weight?
9. Over the last week, how often in the evening did you try not to eat because you were watching your weight?
10. Over the last week, did you take into account your weight when deciding what to eat?

Emotional Eating

11. Over the last week, did you have a desire to eat when you were emotionally upset?
12. Over the last week, did you have a desire to eat when you had nothing to do?
13. Over the last week, did you have a desire to eat when you felt depressed or discouraged?
14. Over the last week, did you have a desire to eat when you are feeling lonely?
15. Over the last week, did you have a desire to eat when somebody let you down?
16. Over the last week did you have a desire to eat when you were cross?
17. Over the last week, did you have a desire to eat when you were expecting something unpleasant to happen?
18. Over the last week, did you get the desire to eat when you were anxious, worried or tense?
19. Over the last week, did you have a desire to eat when things were going against you or when things were going wrong?
20. Over the last week, did you have a desire to eat when you were frightened?
21. Over the last week, did you have a desire to eat when you were disappointed?
22. Over the last week did you have the desire to eat when you were irritated?
23. Over the last week, did you have a desire to eat when you were bored or restless?
External Eating

24. Over the last week, when food tasted good to you did you eat more than usual?
25. Over the last week, when food smelt and looked good did you eat more than usual?
26. Over the last week, when you saw or smelt something delicious did you have a desire to eat it?
27. Over the last week, when you had something delicious to eat did you eat it straight away?
28. Over the last week, if you walked past the baker did you have the desire to buy something delicious?
29. Over the last week, if you walked past a snackbar or a cafe, did you have the desire to buy something delicious?
30. Over the last week, if you saw others eating, did you also have the desire to eat?
31. Over the last week, could you resist eating tempting high caloric foods?
32. Over the last week, did you eat more than usual when you saw others eating?
33. Over the last week, when preparing a meal, were you inclined to eat something?
2. The Block Food Screener

Think about your eating habits over the last week. Include breakfast, lunch, dinner, snacks and eating out.

How many times did you eat a SERVING of each of the following foods?

Guidelines for servings are below:

**A sample serve of Fruit is one of the following:**
- 1 medium piece, eg apple, banana, orange, pear
- 2 small pieces, eg apricots, kiwi fruit, plums
- 1 cup diced pieces or canned fruit
- ½ cup juice
- Dried fruit, eg 4 dried apricot halves
- 1½ tablespoons sultanas

**A sample serve of vegetables is one of the following:**
- 75 g or 1/2 cup cooked vegetables
- 75g or 1/2 cup cooked dried beans, peas or lentils
- 1 cup salad vegetables
- 1 potato

<table>
<thead>
<tr>
<th>Food Item</th>
<th>Less than once per week</th>
<th>About once per week</th>
<th>2-3 times per week</th>
<th>4-6 times per week</th>
<th>Every day</th>
<th>2 or more times per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRUIT JUICE (e.g. orange, apple; fresh, frozen or canned; not sodas or other drinks)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FRUIT (fresh or canned; not including juice)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VEGETABLE JUICE (e.g. tomato juice, V-8, carrot)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GREEN SALAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POTATOES (any kind, including baked, mashed or fried/chips)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VEGETABLE SOUP OR STEW WITH VEGETABLES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANY OTHER VEGETABLES (e.g. green beans, peas, corn, broccoli or any other kind)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Think about your eating habits over the last week. Include breakfast, lunch, dinner, snacks and eating out.

How often do you eat each of the following?

<table>
<thead>
<tr>
<th>Food Item</th>
<th>Never</th>
<th>Once per week</th>
<th>1-2 times per week</th>
<th>3-4 times per week</th>
<th>5 or more times per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINCE BEEF (e.g. in hamburgers, meat burritos, tacos, spaghetti bolognese)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEEF OR PORK (e.g. steak, roast, ribs, or in sandwiches)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FRIED CHICKEN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HOT DOGS, POLISH, ITALIAN OR SPANISH SAUSAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COLD CUTS, LUNCH MEAT, HAM (not low-fat)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BACON OR BREAKFAST SAUSAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SALAD DRESSING (not low-fat)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MARGARINE, BUTTER, FULL FAT MAYONNAISE, OIL (on bread or potatoes or used in cooking)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EGGS (not egg whites only)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIZZA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHEESE, CHEESE SPREAD (not low-fat)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHOLE MILK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FRIED POTATOES (e.g. French fries, hot chips)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORN CHIPS, POTATO CHIPS, POPCORN, CRACKERS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOUGHNUTS, PASTRIES, CAKE, COOKIE, CHOCOLATE (all not low-fat)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICECREAM (not sorbet or non-fat)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Depletion task

For the next five minutes please write about what you did on the weekend and/or what you plan to do this coming weekend.

HOWEVER, WHEN YOU ARE WRITING, DO NOT USE ANY WORDS THAT CONTAIN THE LETTERS 'A' OR 'N'.

E.g. 'I will go to the city'

Ensure that you attempt to form sentences that make sense using words that do not contain 'A' or 'N'.

Click the box below to begin and note that the task will automatically end after 5 minutes so please keep writing until the page changes automatically.
Please answer the following questions:

1. How difficult was the task?

<table>
<thead>
<tr>
<th>Extremely difficult</th>
<th>Moderately difficult</th>
<th>Slightly difficult</th>
<th>Neutral</th>
<th>Slightly easy</th>
<th>Moderately easy</th>
<th>Extremely easy</th>
</tr>
</thead>
</table>

2. How unpleasant was the task?

<table>
<thead>
<tr>
<th>Extremely unpleasant</th>
<th>Moderately unpleasant</th>
<th>Slightly unpleasant</th>
<th>Neutral</th>
<th>Slightly pleasant</th>
<th>Moderately pleasant</th>
<th>Extremely pleasant</th>
</tr>
</thead>
</table>

3. How frustrating was the task?

<table>
<thead>
<tr>
<th>Extremely frustrating</th>
<th>Very frustrating</th>
<th>Moderately frustrating</th>
<th>Slightly frustrating</th>
<th>Not at all frustrating</th>
</tr>
</thead>
</table>

4. How much were you fighting against an urge while working on the task?

<table>
<thead>
<tr>
<th>Extremely</th>
<th>Very much</th>
<th>Moderately</th>
<th>Slightly</th>
<th>Not at all</th>
</tr>
</thead>
</table>

242
4. Stimuli used in stop-signal tasks

Healthy
Unhealthy
1. National Cancer Institute Percentage Energy from Fat Screener

1. Think about your eating habits over the past week. About how often did you eat or drink each of the following foods? Remember breakfast, lunch, dinner, snacks, and eating out. Choose one option for each food.

<table>
<thead>
<tr>
<th>Food Description</th>
<th>1-2 times per week</th>
<th>3-4 times per week</th>
<th>5-6 times per week</th>
<th>Once a day</th>
<th>2 or more times a day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skim milk on cereal or to drink/in coffee</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eggs, fried or scrambled in margarine, butter or oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sausage or bacon, regular-fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Margarine or butter on bread, rolls, pancakes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange juice or grapefruit juice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit (not juices)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef or pork hot dogs, regular-fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheese or cheese spread, regular-fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>French fries, wedges, or hash brown potatoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Margarine or butter on vegetables, including potatoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mayonnaise, regular-fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salad dressings, regular-fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Margarine, butter, or oil on rice or pasta</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Over the past week, when you prepared foods with butter/margarine or ate butter/margarine, how often did you use reduced-fat margarine?

<table>
<thead>
<tr>
<th>Frequency of Use</th>
<th>Didn't use butter/margarine</th>
<th>Almost never</th>
<th>About 1 time out of 4</th>
<th>About half of the time</th>
<th>About 3 times out of 4</th>
<th>Every time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Overall, when you think about the foods you ate over the past week, would you say your diet was high, medium or low in fat?

<table>
<thead>
<tr>
<th>Diet Level</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D: Emails sent to participants for intervention studies presented in Chapter 7 and 8.

1. Emails sent to participants on Day 1 of training

---

**Healthy Eating Study**

**Part 2**

**Part 2 - Day 1**

Welcome to the first day of Part 2 of the Healthy Eating Study.

You will find the link to today's task below:


Each day you will be emailed with a link to task that you have to complete that day

Please try to complete the task at the same time each day and try to limit distraction from other people, music etc.

---

**Contact Details**

Please contact the researcher if you experience any technical difficulties:

[veil2758@uni.sydney.edu.au](mailto:veil2758@uni.sydney.edu.au)
2. Emails sent to participants on Days 2-10

Healthy Eating Study

Part 2 - Day 2
Welcome back to 'Healthy Eating Study'.
You will find the link to today's task below:

http://research.millisecond.com/sydney_psych/HealthyEatingAPart2.web

Contact Details
Please contact the researcher if you experience any technical difficulties:
well3758@uni.sydney.edu.au
Appendix E: Publications relating to this thesis

1. MAINTAINING HEALTHY EATING BEHAVIOUR: EXPERIENCES AND PERCEPTIONS OF YOUNG ADULTS*

Vanessa Allom¹, Barbara Mullan¹

¹School of Psychology, University of Sydney, Australia

*Due to copyright, the version appearing in this thesis is not the final published work
Abstract

Purpose: The prevalence of overweight and obesity is increasing, particularly in young adults who recently have been shown to experience more weight gain than other demographics. Research has focused on factors leading to this weight gain, implicating the abundance of unhealthy foods in the direct environment, yet limited research has examined why some individuals are able to successfully regulate their eating behaviour in this ‘food-rich environment’. The aim of this research was to explore the perceptions and experiences of successful healthy eaters in order to determine factors that distinguish this group from unhealthy eaters.

Methodology: Thirty-five healthy weight young adults, who considered themselves to be healthy eaters, participated in seven semi-structured focus groups. Key questions examined how these individuals regulated their eating behaviour and their perceptions regarding such self-control processes.

Findings: Thematic analysis revealed that individuals who are successful at maintaining healthy eating behaviour perceive the same barriers as non-successful individuals, yet are able to employ self-control techniques to overcome these barriers. Additionally, continually exerting self-control appeared to facilitate the formation of healthy eating habits.

Implications: Future research may benefit from attempting to modify self-control ability and develop healthy habits.

Originality: While factors leading to obesity and the cognitions of those who are overweight have been extensively examined, limited research has focused on those who are able to regulate their eating behaviour. Additionally, limited qualitative research has examined implicit theories of self-control in an eating context.

Keywords: healthy eating, weight maintenance, focus groups, self-control, young adult
Maintaining healthy eating behaviour: Experiences and perceptions of young adults

Overweight and obesity are major health problems in many countries, with 61% of the Australian population (Australian Bureau of Statistics, 2009) and 69% of the United States population (Allender et al., 2006) being either overweight or obese. Young adults are of particular concern as recent research has indicated that this group experience more weight gain than any other (Barr et al., 2006; Gordon-Larsen et al., 2004). Importantly, this weight gain in young adults has been shown to contribute to the incidence of obesity in later life (i.e. by the mid-30s; Guo et al., 2000). Given the health risks associated with obesity including cardiovascular diseases, hypertension, cancer and diabetes (Visscher and Seidell, 2001), many individuals have become increasingly concerned with their eating behaviour. However, the current food-rich environment, in which unhealthy choices are readily available, makes achieving and maintaining the goal of eating healthily difficult.

The accessibility of food and the presence of cues in the environment, such as the sight, smell and palatability of food has been found to powerfully influence eating behaviour (Wansink, 2004; Maas et al., 2012). For example, Harris et al. (2009) demonstrated that viewing television advertisements increased consumption of food products, regardless of hunger level. While this provides insight into how people are influenced by cues in the environment, it is not clear how successful healthy eaters navigate this environment, or what strategies they engage in to lessen the negative impact of these cues.

Recent research examining food-related cognitions and behaviours of non-clinical populations has suggested that self-control; the ability to regulate immediate desires in order to reach long term goals, plays an important role in healthy eating (Allom and Mullan, 2012; Houben and Jansen, 2011). However, while the role of self-control has been assessed using self-report scales of related facets such as impulsivity (Grubbs and Carter, 2002) and/or
cognitive tasks said to objectively measure such facets (Hofmann et al., 2009), little is known about individuals’ perceptions of self-control and how this might influence behaviour.

Given that previous research has tended to focus on those who are unable to regulate their eating behaviour, the aim of the present study was to qualitatively explore the perceptions and experiences of a population of healthy weight individuals to provide insight into how these individuals are able to successfully maintain healthy eating behaviour. Specifically, the aim of this research was to determine whether the success of healthy eaters is due to different barriers faced by these individuals, compared to those faced by unhealthy eaters, or if healthy eaters are better able to cope with the same barriers. These factors have the potential to inform future quantitative research and develop alternatives to current interventions in young people which are generally not successful at supporting healthy eating maintenance (Hebden et al., 2012).

Methods

Participants
Forty-one participants enrolled in the study and provided weight status information. One participant who was classed as underweight (BMI = 17.05) was excluded, debriefed and provided with information regarding healthy weight and counselling services. Five participants did not attend, leaving 35 participants (4-6 in each group; 7 groups in total). The mean BMI of the remaining sample was 21.47 (SD = 1.53). No participant indicated having an eating disorder in the past or present. The mean age of participants was 19.46 years (SD = 2.31), identified as being either Australian (68.6%; n = 24) or Asian (31.4%; n = 11) and the majority of the sample was female (71.4%; n = 25).

Procedure
The study was approved by the University Human Research Ethics Committee. Participants enrolled in an undergraduate psychology course at an Australian university were recruited
using an online registration system and participated for course credit. All participants gave their informed consent before providing self-reported demographic information. Those who were 18 years or older, considered themselves to be healthy eaters, had maintained a healthy weight (BMI between 18.50 and 24.99; since they were 18) and indicated no current or prior eating disorders were then invited to join a focus group. Sessions lasted approximately one hour and took place from 2pm to 3pm weekdays on the university campus.

Sessions were audio-taped and transcribed verbatim. The transcripts were entered into NVivo 9 (QSR International, 2010) and reviewed line-by-line for concepts, themes and ideas. A coding scheme was developed based on the previously described literature and included: facilitators of healthy eating, barriers to maintaining healthy eating and perspectives on self-control and the role of environment. A thematic framework was then created which involved determining the primary and secondary themes. Themes were discussed and agreed upon by the authors.

**Measures**

**Focus group questions**

Focus groups were guided by a semi-structured interview schedule based on the five categories of questions and probes developed by Krueger and Casey (2009). Firstly, a warm-up question, designed to acquaint participants, was asked (“Tell us your name and your favourite food.”). An introductory question followed which began discussion of the topic (“Describe a healthy diet.”). Transition questions were used to move into and between key questions and to help participants grasp the central issues (“Describe your eating behaviour”). Key questions addressed the primary concerns of the study (“What enables/impedes the maintenance of your healthy eating behaviour? Prompt: Routine, internal states, particular situations. Describe particular successes or struggles you’ve encountered while trying to eat healthily. Prompt: maintaining focus on healthy eating goal, self-control”). Finally, a
concluding question closed the discussion and helped researchers determine where to place emphasis (“We are interested in how healthy eaters differ from unhealthy eaters, what advice do you have for us?”).

A pilot focus group was conducted to determine the appropriateness of questions for eliciting responses to the target issues, and for the optimal length of focus groups. Data from the pilot focus group were not included in the analysis.

Results

Four themes were identified that represented the healthy eating experiences and perceptions of healthy weight young adults. Table 1 provides a summary of themes. Primary and secondary themes are reported below and representative quotes are presented in Tables 2-5.
Healthy eating enablers and barriers

Self-control

Self-control, described as ‘willpower’ and ‘dedication’, was consistently noted as a necessary determinant of healthy eating (see Table 2). Participants clearly attributed their success at maintaining healthy eating behaviour, to higher order cognitive processes. Particularly, focusing on the long-term goal of achieving a healthy lifestyle rather than the short-term goal of seeking gratification from the consumption of high-calorie foods was described as an
enabler to healthy eating. Participants speculated that unhealthy eaters find this task more difficult than they did, and are thus more likely to abandon their healthy eating goals.

**Success as a facilitator or inhibitor**

A factor that was seen to be both a facilitator and an inhibitor of healthy eating was perceived success. Success could refer to either losing/maintaining weight or adhering to a healthy diet. Participants described that experiencing success facilitated healthy eating behaviour as the goal became achievable and salient, whereas not perceiving any result was discouraging and led to abandonment of healthy eating behaviour. Participants also discussed how experiencing success may be detrimental in that it provided a license to return to previous unhealthily eating behaviours. This was sometimes associated with cycling between dieting and over-indulging. However, healthy eaters in this sample appeared to be somewhat resilient to these setbacks and expressed optimism in the face of these challenges.

**Cognitive framing**

The ability to maintain healthy eating behaviour was attributed to the way in which this goal was cognitively framed. Participants described their healthy eating behaviour as part of an ongoing healthy lifestyle rather than a temporary diet, improving the likelihood of maintenance. Correspondingly, participants held negative opinions towards dieting and all agreed that such short term measures inevitably led to failure.
Table 2
Representative quotes for Theme 1: Healthy eating enablers and barriers, with focus group indicated

<table>
<thead>
<tr>
<th>Self-Control</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“Mental power, definitely”</td>
<td>2</td>
</tr>
<tr>
<td>“You have to be really committed”</td>
<td>2</td>
</tr>
<tr>
<td>“Sticking to your goals. So if you see chocolate you just think well not having this is good for me in the long term”</td>
<td>3</td>
</tr>
<tr>
<td>“It benefits you in the long run but it takes so long so you have to be willing to wait”</td>
<td>4</td>
</tr>
<tr>
<td>“Yeah if it’s not immediate a lot of the time people are like ‘oh screw it’”</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Success as facilitator or inhibitor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“By seeing results you feel more motivated to keep going but I think someone who wasn’t seeing immediate results or results after a while may be a bit discouraged to keep on going and think ‘what’s the point?’”</td>
<td>2</td>
</tr>
<tr>
<td>“Yeah, that happens to everyone, I guess you just have to keep going or, like, be realistic about it [healthy eating]”</td>
<td>2</td>
</tr>
<tr>
<td>“On the other hand some people see results and think they’re doing well so they say oh I can have some chocolate”</td>
<td>4</td>
</tr>
<tr>
<td>“People eating healthily for a while start to feel good but then they start to think they can indulge more and they’re stuck in this cycle”</td>
<td>6</td>
</tr>
<tr>
<td>“I do tend to think like that but I just keep reminding myself how good I’d feel if I kept at it [eating healthily]”</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cognitive framing</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“It [healthy eating] should be a lifestyle”</td>
<td>1</td>
</tr>
<tr>
<td>“I think it’s a mindset that they need to keep in their minds and integrate it into their lifestyle not just during the period of time of their diet”</td>
<td>3</td>
</tr>
<tr>
<td>“Restriction”</td>
<td>1</td>
</tr>
<tr>
<td>“Deprivation”</td>
<td>2</td>
</tr>
<tr>
<td>“Boring”</td>
<td>4</td>
</tr>
<tr>
<td>“Starvation”</td>
<td>7</td>
</tr>
<tr>
<td>“…diets don’t work because they are like a temporary thing. You need to actually make a change- it [healthy eating] is something that you are now doing forever”</td>
<td>4</td>
</tr>
</tbody>
</table>

Coping with environment barriers

Availability of high-calorie foods
It was agreed that the environment provides multiple sources of inexpensive, high caloric foods, which results in overeating and contributes to poor dietary choices (see Table 3). Participants commented on how the availability of food encourages individuals to eat regardless of whether they are hungry or not. However, participants believed that to some extent, this was a misinterpretation. Particularly, the notion that fast food is convenient and inexpensive was challenged. Participants discussed how people often choose fast-foods as they believe they do not have enough time to prepare healthy meals, when in actuality preparing healthy meals is not always a time-consuming event.

*Cues to action*

External factors such as advertisements and internal factors such as sensory and biological cues were seen as influencers of eating behaviour. While participants described their awareness of these cues, they described being less responsive and better able to resist the temptations stimulated by these cues in comparison to their peers. Yet, it was noted that it was not always possible to ignore external cues, particularly when participants had consumed alcohol, were stressed or bored. In order to combat the influence of such cues, participants physically altered their environments. For example, during a lunch break rather than exposing themselves to unhealthy options, they would walk to locations that offered healthy options. Additionally, they would make unhealthy food less accessible by removing tempting items from their pantry or fridge.
### Table 3

**Representative quotes for Theme 2: Coping with environmental barriers, with focus group indicated**

<table>
<thead>
<tr>
<th>Availability of high-calorie foods</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“There’s just such a high availability of bad food”</td>
<td>3</td>
</tr>
<tr>
<td>“It’s so easy to walk into McDonalds or buy a bag a chips”</td>
<td>3</td>
</tr>
<tr>
<td>“Yeah if the opportunity is there people are like okay I’ll eat it when really they should be questioning whether they’re actually hungry or not”</td>
<td>4</td>
</tr>
<tr>
<td>“And the idea of convenience of fast food like that mindset that it’s quick and easy and it will fill you up and it’s like the complete opposite as well, because once you have it you’re never satisfied, it digests quickly and you’re looking for something else to eat”</td>
<td>3</td>
</tr>
<tr>
<td>“A lot of people think it’s too hard to eat healthy like ‘Aww, it’s too expensive’”</td>
<td>5</td>
</tr>
<tr>
<td>“It’s not always more expensive”</td>
<td>5</td>
</tr>
<tr>
<td>“I definitely feel it’s cheaper”</td>
<td>5</td>
</tr>
<tr>
<td>“People think there’s not enough time but they’ve probably never even tried. I make my lunch every day for Uni, it really doesn’t take long”</td>
<td>7</td>
</tr>
<tr>
<td>“Yeah I guess it is a bit of an excuse”</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cues to action</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“I guess advertisements really affect people, like if they see a picture of some new or delicious food they want to try it”</td>
<td>5</td>
</tr>
<tr>
<td>“…it’s the smell, like if you pass a bakery and it’s hard to stop thinking about it”</td>
<td>7</td>
</tr>
<tr>
<td>“Stuff like that use to make me eat more but now when I get full I just stop. Whatever I want to eat, I eat, but when I’m full I stop”</td>
<td>1</td>
</tr>
<tr>
<td>“If I have lack of sleep I really want to eat something.”</td>
<td>1</td>
</tr>
<tr>
<td>“If you’ve been out and it’s late at night drinking then yes, it’s harder to control”</td>
<td>3</td>
</tr>
<tr>
<td>“You eat more when you’re studying, bored eating or procrastination”</td>
<td>3</td>
</tr>
<tr>
<td>“I always walk away to Glebe Point Road and get something I know is healthy”</td>
<td>1</td>
</tr>
<tr>
<td>“Yes or prepare my own food”</td>
<td>1</td>
</tr>
<tr>
<td>“I don’t have easily accessible unhealthy stuff at home”</td>
<td>4</td>
</tr>
<tr>
<td>“Just having healthy foods available in your fridge”</td>
<td>5</td>
</tr>
</tbody>
</table>

### Nature of self-control

**Limited versus non-limited resource**

While participants credited their success to their ability to exert self-control, it was consistently noted that this ability was a limited resource where repeated exertion led to
unhealthy eating (see Table 4). This reflects previous comments which suggested that at times participants were more susceptible to environmental cues. However, in order to combat the limited nature of self-control participants exercised self-control in moderation and allowed a few occasions of unhealthy eating. Participants also noted that with multiple successful healthy eating attempts, the process of exerting self-control became easier.

*Carry-over effects*

Participants found that exerting self-control in one area of their life carried over to successful regulation of another behaviour such as exercise or studying. However, some individuals described how when they consistently denied themselves snack foods they experienced poorer self-control in another area, such as binge drinking.

*Planning and monitoring*

Participants described specific abilities that they regarded as responsible for their success, including planning. It was noted that the ability to plan allowed these individuals to better navigate their environment, as unhealthy options did not distract them from their healthy eating goal. Further, planning enabled participants to eat regularly which offset the chance of engaging in unhealthy eating. Participants also described engaging in self-monitoring, whereby they were consistently aware of what they were eating rather than engaging in mindless snacking or overindulgence.
Table 4
Representative quotes for Theme 3: Nature of self-control, with focus group indicated

<table>
<thead>
<tr>
<th>Limited versus non-limited resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>“If you deprive yourself from something for long enough you want it” 7</td>
</tr>
<tr>
<td>“I don’t think it [sustained self-control] is possible... it just depends like how extreme the restrictions are” 5</td>
</tr>
<tr>
<td>“It’s better to only withhold to a limit. Maybe like over a week have a snack” 6</td>
</tr>
<tr>
<td>“It’s definitely easier to maintain than an overall restriction, you wouldn’t be able to keep that up for very long” 6</td>
</tr>
<tr>
<td>“I don’t think anyone can maintain it long term” 2</td>
</tr>
<tr>
<td>“It’s not something you can have forever” 1</td>
</tr>
<tr>
<td>“Just practicing saying ‘no’. If someone offered me something I’d always say ‘yeah’ but I found when I kept saying ‘no, I’m okay’ it got easier” 5</td>
</tr>
<tr>
<td>“I think you know watching what you put in your mouth it does help to an extent like if you don’t eat chocolate for a week, you’ll find that you get better” 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carry-over effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Yeah it helps with everything, you’ll find that if you’re able to stick to an exercise plan you’ll be able to study better and all kinds of things” 3</td>
</tr>
<tr>
<td>“Completely matches what’s going on in the rest of my life so if I’m having a crap time I’ll probably eat whatever I want” 4</td>
</tr>
<tr>
<td>“Also if you’re like substituting or anything like that yeah so like if you stop eating sweets you substitute it with something else that’s bad like drinking [alcohol]” 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Planning and monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>“I set it all out for myself- what I’m eating and when” 4</td>
</tr>
<tr>
<td>“So yeah I’m pretty good at planning I guess” 3</td>
</tr>
<tr>
<td>“Like having a plan really helps, so not like you eat whatever you want but know what good things you can eat and where they’re available” 4</td>
</tr>
<tr>
<td>“I would eat regularly; I would eat at the same time every day” 7</td>
</tr>
<tr>
<td>“I do make sure I’m aware of what I’m eating, make sure it’s not mindless” 4</td>
</tr>
<tr>
<td>“I always pull myself up like; ‘No you can’t eat that.’ I’m always monitoring, I guess it’s like a constant thing” 7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Habit</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Increasing automaticity</th>
</tr>
</thead>
</table>

Participants also described how after a period of successfully maintaining their behaviour, this process, and healthy eating itself, had become somewhat automatic (see Table 5). It was
suggested that developing healthy habits would be key in helping others to maintain healthy eating behaviour. Participants described their behaviour as a transition from being initially intention based and under cognitive control to a less effortful process. Once behaviour had become habitual, external cues seemed to have less of an influence.

**Breaking routine**

However, when routine was broken, for example due to a social event, participants noted that they were likely to eat unhealthily and experience some difficulty resuming their previous eating behaviour and recruiting self-control resources. Others noted that planning was an important self-control technique to utilise in these situations.

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Representative quotes for Theme 4: Habit, with focus group indicated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increasing automaticity</strong></td>
<td></td>
</tr>
<tr>
<td>“I don’t think it’s a conscious thing for me anymore that’s just how it happened for so long and it’s become routine”</td>
<td>6</td>
</tr>
<tr>
<td>“Sometimes you get into the routine and eating healthy just keeps kind of going, you don’t think about it”</td>
<td>5</td>
</tr>
<tr>
<td>“Maybe it needs to be a more subconscious thing because people are very aware of their diets but it just comes naturally to me”</td>
<td>7</td>
</tr>
<tr>
<td>“You contemplate and you think about it but yeah as soon as you get it over and done with its easier from there it’s like you have to force yourself to do that”</td>
<td>5</td>
</tr>
<tr>
<td>“I guess like getting over the initial hump of watching what you’re eating and once you’ve gotten use it you don’t tend to be affected by cravings so much”</td>
<td>7</td>
</tr>
</tbody>
</table>

| **Breaking routine** | | |
| “It’s sometimes difficult on the weekend when you’re doing different things and it’s hard to keep in routine” | 3 |
| “I guess that’s where planning comes in” | 3 |

**Discussion**

This is the first study to investigate the factors that influence the maintenance of healthy eating behaviour within a healthy weight population of young adults. The primary themes
that emerged indicated that while healthy eaters face the same barriers to healthy eating as others, they tend to respond differently by employing techniques to overcome these barriers including altering their environment and engaging in self-control.

The first theme in which participants discussed how a ‘diet’ is inherently temporary and leads to failure has been supported by previous literature (Mann et al., 2007). This sample differed in that participants made dietary choices with the mindset of fulfilling a healthy lifestyle, inherent in which is the goal of maintenance. Framing in this way may establish an intention to maintain this behaviour and if plans are made to carry out this intention, temptations should be easier to overcome (Gollwitzer, 1999).

The perception that the experience of success may lead to setbacks in those with short term dieting goals is consistent with the restrained eating literature where it has been found that individuals who attempt to strictly control their intake cycle back and forth between restricting and indulging (Amigo and Fernández, 2007; Hawks et al., 2008). Participants in this sample highlighted the importance of setting and reaching realistic goals as this increased the salience and achievability of long term healthy eating. This reflects findings that implicate perceived behavioural control and self-efficacy in the execution of health behaviours (Conner et al., 2002).

Participants discussed the role that the external environment plays on eating behaviour, reflecting the finding that the salience of food can initiate unplanned consumption or increase consumption in general (Remick et al., 2009). Importantly, participants described techniques that they either consciously or automatically engaged in to avoid the influence of environmental cues. Namely, participants either re-interpreted their environment or manipulated the availability of potential triggers to unhealthy eating. Previous research has found that if the salience of these cues is reduced, their influence on consumption is reduced (Coelho et al., 2009). Additionally, exposing individuals to a healthy eating goal has been
shown to outweigh the influence of the cue to eat unhealthily (Papies and Hamstra, 2010). The current results suggest that those who maintain healthy eating behaviours may do so as a result of efforts to reduce the salience of cues in the environment.

The mechanism which enables healthy eaters to cope with temptations from their environment appears to be self-control. Participants explicitly described self-control techniques such as self-monitoring (Baumeister et al., 2006), planning (Wong and Mullan, 2009) and delay of gratification (Daugherty and Brase, 2010), to which they attributed their success. Specifically, healthy eaters seem to be able to maintain their healthy eating goal even when faced with challenges or distraction, perhaps implicating the role of working memory. Working memory can be described as the ability to keep information in an active, quickly retrievable state and shield this information from distraction (Kane et al., 2001). Indeed, research has shown that presenting the goal to eat healthily guided the eating behaviour of those with a superior working memory capacity but not those with a low capacity (Hofmann et al., 2008). Additionally, participants seemed to be less reactive to cues, perhaps implicating the role of inhibitory control. It has been shown that those who are better able to withhold a pre-potent response are also less likely to engage in unhealthy eating behaviour (Veling et al., 2011).

Some participants in the current sample described how they experienced a lack of self-control in other areas when they resisted the temptation of unhealthy foods, implicating a depletion effect; however, others also experienced the generalisation of self-control whereby success in one domain led to another. The strength model of self-control (Baumeister et al., 2007) also predicts that exercising self-control will leave one depleted and less able to exert self-control in other contexts (Hagger et al., 2009). But it has also been found that exercising self-control in one area leads to better self-control in other areas (Oaten and Cheng, 2006). Thus, it is likely that while individuals become exhausted in the short term, after a period of
recovery and repeated exercising of self-control, this resource strengthened, accounting for the carry-over effects and the perceived improvement in self-control exertion described by the current sample.

Experimental research to improve self-control has demonstrated that participants trained on a cognitive task related to inhibitory control not only improved their inhibitory control, as measured by another task, but also consumed less chocolate than those who had not been trained (Houben and Jansen, 2011). While more research is required to replicate these results, healthy eating within young adults may be facilitated through cognitive training. Furthermore, participants in the current sample indicated that as their self-control improved, the need to consciously engage these resources declined, and exerting self-control, and thus healthy eating itself, came to reflect habitual processes. Research has suggested that habits are formed when a specific behaviour is performed frequently and consistently in the same situation for the same purpose (Lally et al., 2010; Lally et al., 2011). It is likely that the stable goal to eat healthily and the repeated enactment of self-control techniques to achieve this goal, facilitated habit formation.

**Limitations**

As several of the participants described behaviours similar to that of restrained eaters, the current study may have benefited from the inclusion of a measure of dietary restraint to determine the level of restrained eating within this sample. However, the majority of participants indicated that restricting their intake did not lead to successful maintenance of healthy eating, therefore, while some of the participants may have been classed as restrained eaters in the past, it is unlikely that these participants remained restrained eaters. Additionally, the sample was primarily comprised of women with low BMI and of high socioeconomic status which may not be representative of the Australian population and thus impacts on the generalisability of these findings. Specifically, while male participants agreed
with female participants on most themes, including environmental influences, fewer males described experiences with dieting. Further, university students may have different economic influences on food and therefore describe and experience different food environments to those less educated and living in less affluent areas, limiting the applicability of these findings to other groups of young adults. Finally, perceptions and practices regarding young adults’ exercise behaviour may provide further insight into weight maintenance, however exercise behaviour was beyond the scope of the current research which focused specifically on healthy eating, and has been qualitatively examined previously (Grubbs and Carter, 2002; Allender et al., 2006).

**Conclusion**

These findings reveal the processes underlying healthy eating, and specifically highlight the factors to which healthy eaters attribute their success. Healthy eaters provided insight into the nature of these processes including self-control and the manner by which healthy eating behaviours become habitual. Qualitative research addressing the factors that enable healthier eaters to maintain this behaviour is important as overweight and obesity are significant problems within young adults, for whom current weight status is predictive of future overweight and obesity and current interventions are unsuccessful.
References


QSR International (2010), NVivo qualitative data analysis software. 9 ed.: QSR International Pty Ltd.


2. INDIVIDUAL DIFFERENCES IN EXECUTIVE FUNCTION PREDICT DISTINCT EATING BEHAVIOURS

Vanessa Allom\textsuperscript{1}, Barbara Mullan\textsuperscript{1}

\textsuperscript{1}School of Psychology, University of Sydney, Australia
Abstract

Executive function has been shown to influence the performance of health behaviours. Healthy eating involves both the inhibitory behaviour of consuming low amounts of saturated fat and the initiatory behaviour of consuming fruit and vegetables. Based on this distinction, it was hypothesized that different executive functions would predict these behaviours.

Measures of inhibitory control and updating were administered to 115 participants across two days. One week later fruit and vegetable and saturated fat consumption were measured. Regression analyses revealed a double dissociation effect between the different executive function variables and the prediction of eating behaviours. Specifically, inhibitory control, but not updating, predicted saturated fat intake, while updating, but not inhibitory control, was related to fruit and vegetable consumption. In both cases, better executive function capacity was associated with healthier eating behaviour. The results support the idea that different executive functions predict distinct behaviours- inhibitory control is important for behaviours that require the stopping of a response such as limiting saturated fat intake, while updating (the ability to maintain and update goals) appears important for initiatory behaviours such as fruit and vegetable consumption. The findings suggest that interventions aimed at improving these behaviours should address the relevant facet of executive function.

Keywords: executive function, working memory, inhibition, healthy eating
Individual differences in executive function predict distinct eating behaviours

Healthy eating involves consuming appropriate amounts of particular food groups in order to maintain a healthy weight and reduce the risk of chronic diseases such as cancer and coronary heart disease (Mente, de Koning, Shannon, & Anand, 2009). Specifically, it is recommended that individuals consume a limited amount of saturated fat and a substantial amount of fruit and vegetables (National Health and Medical Research Council, 2003; World Health Organization, 2000). In Australia, the national guidelines suggest that an individual’s saturated fat intake should not exceed 10% of their total energy intake; that is, no more than 24g per day; and that individuals should consume two servings of fruit and five servings of vegetables each day (National Health and Medical Research Council and New Zealand Ministry of Health, 2006). Similar guidelines exist for the UK and the USA (Food Standards Agency, 2007; US Department of Agriculture & US Department of Health and Human Services, 2010).

Despite awareness of the benefits of healthy eating, individuals experience difficulty adhering to these guidelines (Australian Institute of Health and Welfare, 2012; McLennan & Podger, 1998). This is reflected in the consistent finding that individuals often fail to carry out their intentions (McEachan, Conner, Taylor, & Lawton, 2011), and suggests that while motivation to carry out a goal-directed behaviour is important, the ability to translate this motivation into action is key. A construct that has been implicated in the successful execution of health behaviour goals is self-regulation (Hagger, 2010; Hofmann, Schmeichel, & Baddeley, 2012). Self-regulation has been defined as the wilful regulation of internal drives in response to environmental triggers, in order to manage behaviour (Baumeister, Schmeichel, & Vohs, 2007). Research has found that self-regulation is important for both the adoption of health enhancing behaviours such as breakfast consumption (Wong & Mullan,
2009) and the avoidance of health risk behaviours such as binge drinking (Mullan, Wong, Allom, & Pack, 2011).

Executive functions are said to subserve the capacity to self-regulate, wherein individual differences in these cognitive abilities predict the translation of intention into action (Hofmann et al., 2012). Two categories of executive functions which are influential in the performance of goal-directed behaviour include inhibitory control and updating (Miyake et al., 2000). Inhibitory control refers to the ability to purposely override dominant, automatic or prepotent responses when required in order to achieve a goal. In the case of healthy eating, this may involve inhibiting the desire to consume high-fat palatable foods in order to meet the goal of adhering to a healthy diet. Inhibitory control has been assessed using behavioural tasks such as the Stroop task (Stroop, 1935), Stop Signal Task (SST; Logan, Schachar, & Tannock, 1997) and the Go/No-Go Task (GNG; Miller, Schäffer, & Hackley, 1991). In the Stroop task, participants are required to name the colour of written colour words while inhibiting the tendency to read the word itself. In the SST participants are required to respond as quickly as possible on a choice task, unless a signal to stop responding is presented, while in the GNG participants have to response as fast as possible to a set of stimuli while withholding responses to another set.

Updating is closely related to working memory and refers to the ability to keep goal-relevant information in an active, quickly retrievable state and shield this information from distraction (Miyake et al., 2000). In the case of healthy eating, updating may be necessary to ensure that the goal to eat healthily is active and retrievable when faced with unhealthy choices. Updating has been measured using tasks including the n-back (Jaeggi et al., 2010) and the Operation Span Task (OSPAN; Kane, Conway, Miura, & Colflesh, 2007). In the n-back, a sequence of stimuli is presented and participants must indicate when the current stimulus matches one n steps earlier in the sequence. Working memory needs to be updated
with each new presentation to monitor what the current stimulus must be compared to. The OSPAN involves confirming the correctness of mathematical equations while keeping a letter string active in working memory. This letter string must be updated with each new presentation and recalled in the correct order when prompted.

Previous research investigating the role of executive function in eating behaviour has demonstrated that deficits in performance on these measures are associated with poorer eating behaviour and/or weight outcomes. For example, Allan, Johnston, and Campbell (2010) demonstrated that poorer Stroop performance was associated with greater chocolate consumption in those who intended to avoid high calorie food, suggesting that inhibitory control is necessary to carry out healthy eating goals. Further, obese participants tended to perform worse on the Stroop compared to healthy controls (Fagundo et al., 2012; Gunstad et al., 2007), indicating a potential association between inhibitory control and weight status. Research examining the relationship between SST and eating behaviour has demonstrated similar findings. For example, Nederkoorn, Houben, Hofmann, Roefs, and Jansen (2010) demonstrated that those who performed poorer on the SST and who had strong implicit preferences for snack food gained the most weight over a year, suggesting that inhibitory control is necessary to regulate impulses towards palatable foods. Similarly, Hofmann, Friese, and Roefs (2009) demonstrated that amongst those who performed poorly on the SST, implicit attitudes towards chocolate predicted chocolate consumption. Additionally, Hendrick, Luo, Zhang, and Li (2011) demonstrated that lean women, in comparison to obese women, showed greater activation in brain regions associated with saliency processing on stop trials than go trials suggesting that normal weight individuals may attend more to cues to inhibit undesired behaviour. Importantly, several studies have demonstrated that performing a SST in which unhealthy food stimuli are paired with stop signals resulted in less consumption

Regarding inhibitory control measured using the GNG, Hall, Fong, Epp, and Elias (2008) and Hall (2012) found an association between GNG performance and eating behaviour such that those higher in inhibitory control carried out their healthy eating behaviour intentions; however, several other researchers have failed to find such a relationship (Allan, Johnston, & Campbell, 2011; Collins & Mullan, 2011; Jasinska et al., 2012). While both the SST and GNG measure inhibitory control, the discrepancy in the predictive validity of these tasks may be explained by the fact that the two paradigms reflect different kinds of inhibition, which may be differentially related to health behaviour. That is, GNG performance is said to reflect bottom-up ‘automatic inhibition’ while SST reflects top-down ‘controlled inhibition’ (Verbruggen & Logan, 2008). Automatic inhibition is involved in goal-directed behaviour when stimulus-response associations are sufficient to activate goal representations; however, when these associations are weak or when the suppression of familiar actions is necessary, controlled inhibition is required. Therefore, for behaviours such as healthy eating, which require resisting palatable foods, controlled inhibition may be more relevant. Indeed, research has shown that improvements in controlled inhibition are more likely to translate to improvement in health behaviour than improvements in automatic inhibition (Thorell, Lindqvist, Bergman Nutley, Bohlin, & Klingberg, 2009; Frederick Verbruggen, Adams, & Chambers, 2012).

Updating has also been shown to relate to eating behaviour. Specifically, Hege et al. (2013) found that poorer performance on an n-back task which included food stimuli was related to poorer weight outcomes in a lifestyle intervention. Similarly, Stingl et al. (2012) demonstrated that increased body weight was associated with poorer performance on the same task and suggested that the effect was driven by increased attention to the food objects.
Higgs, Rutters, Thomas, Naish, and Humphreys (2012) offered support for this claim with the finding that normal weight participants showed facilitated detection of food cues when these cues were held in working memory, while Shaw and Tiggemann (2004) demonstrated that a specific working memory impairment was present in those who were preoccupied with thoughts of food. In terms of studies using the OSPAN, Hofmann et al. (2009) and Hofmann, Gschwendner, Friese, Wiers, and Schmitt (2008) demonstrated that implicit attitudes predicted chocolate consumption within individuals who performed poorly on this task. Conversely, amongst those who performed better on the task, the goal to forgo sweets predicted behaviour (Hofmann et al., 2008). These results indicate that having a goal to eat healthily may only be beneficial when an individual has sufficient ability to maintain and update this goal.

The majority of research examining the relationship between executive function and eating behaviour has focused on unhealthy eating behaviour, finding that poorer inhibitory control and updating ability are associated with increased consumption of unhealthy foods. The relationship between consumption of healthy foods, such as fruits and vegetables, is less clear (Allom & Mullan, 2012). Hall et al. (2008) demonstrated that the relationship between intention and fruit and vegetable consumption was stronger for those with greater inhibitory control. However, when using the same measure of inhibitory control and a similar measure of behaviour in a later study, Hall (2012) failed to demonstrate a comparable relationship with non-fatty food consumption. Several other researchers have also struggled to replicate this effect (Allan et al., 2011; Collins & Mullan, 2011). Additionally, researchers have found that self-report measures of inhibitory control predicted unhealthy food outcomes but not healthy food outcomes (Jasinska et al., 2012; Mullan, Allom, Brogan, Kothe, & Todd, 2014), suggesting that inhibitory control may not play a role in the consumption of healthy foods.
Several studies have also attempted to link healthy eating behaviour to improved updating processes in later life. For example, Kang, Ascherio, and Grodstein (2005) found that total vegetable intake was associated with less cognitive decline in ageing participants. Péneau et al. (2011) also found that higher fruit intake was related to better verbal memory, while Sabia et al. (2009) found that eating less than two serves of fruit and vegetables was associated with poorer executive function and memory. Additionally, Kesse-Guyot et al. (2011) found that better adherence to nutritional recommendations was significantly associated with better verbal memory. While these studies appear to demonstrate a causal link between consuming healthy foods and improved cognitive performance, the direction is still unclear and is likely to be bi-directional (Francis & Stevenson, 2013). Thus, a superior ability to update and maintain goals may enable fruit and vegetable consumption.

The aim of this study was to determine whether individual differences in two categories of executive function amongst participants with healthy eating intentions could predict two healthy eating behaviours: saturated fat intake and fruit and vegetable consumption. Individuals with sufficient intention to eat healthily were recruited so that behaviour was a reflection of individual differences in executive function rather than motivation. It was hypothesised that inhibitory control would predict saturated fat intake such that those with a superior inhibitory control capacity would consume less saturated fat. It was also expected that those with a superior updating capacity would also consume less saturated fat. It was hypothesised that updating would predict fruit and vegetable consumption, such that those with a superior updating capacity would consume more fruit and vegetables. However, inhibitory control was not expected to play a role in fruit and vegetable consumption. Based on previous research which showed that eating behaviour is also influenced by factors such as gender, BMI and eating-related cognitions including dietary restraint (tendency for an individual to consciously restrict food intake due to concerns about
weight), external eating (tendency to eat in response to food-related stimuli or cues, regardless of internal state of hunger or satiety) and emotional eating (tendency to respond to negative emotions by increasing food intake; Jansen et al., 2009; Jasinska et al., 2012; van Strien, Herman, & Anschutz, 2012), these variables were controlled for. It was expected that the hypothesised relationships between inhibitory control, updating and eating behaviour would persist when controlling for BMI, gender and eating-related cognitions.

Method

Participants

One hundred and fifteen normal to overweight undergraduate students from a variety of disciplines (mean age: 19.79 years, $SD = 1.95$, 83 females) were recruited to participate in a study on self-control and eating behaviour in exchange for course credit. Inclusion criteria included holding an intention to eat healthier, not colour blind, fluent in English, having regular access to the internet, and having no current or prior diagnosis of an eating disorder. All participants provided informed consent before taking part in the study, which was approved by the university Human Research and Ethics Committee.

Materials and measures

BMI and eating disorder status. BMI was calculated from participants’ self-reported height and current weight. Participants were also asked to indicate the presence of a current or lifetime eating disorder diagnosis.

Eating & food related cognitions. Eating-related cognitions were measured using the Dutch Eating Behaviour Questionnaire (van Strien, Frijters, Bergers, & Defares, 1986) which consists of 33 items assessing restrained eating (10 items), external eating (10 items) and emotional eating (13 items). Responses ranged from: never (1) to very often (5) and subscale scores reflected the weighted average of relevant items. These subscales have been shown to have high internal consistency, high validity for food consumption, and high convergent and
discriminative validity (van Strien, Frijters, Van Staveren, Defares, & Deurenberg, 1986). All subscales had good internal consistency in the present sample (restrained eating: $\alpha = 0.91$; external eating: $\alpha = 0.83$; emotional eating: $\alpha = 0.94$).

*Eating Behaviour.* The Block Food Screener (Block, Gillespie, Rosenbaum, & Jenson, 2000), which has been validated against the 1995 Block 100-item Food Frequency Questionnaire was used to measure saturated fat intake and fruit and vegetable consumption. For saturated fat intake, participants indicated how often they ate 17 meat and snack items on a 5 point scale ranging from: never (0), to 5 or more times per week (4). Scores were summed and entered into the validated formula in order to calculate daily saturated fat intake in grams. For fruit and vegetable consumption, participants indicated how often they ate seven fruit and vegetable items on a 6 point scale ranging from: less than once per week (0), to 2 or more times per day (5). Scores were summed and entered into the validated formula to calculate servings per day according to the pyramid definition of a serving of fruit or vegetable (US Department of Agriculture & US Department of Health and Human Services, 2010).

*Stroop interference task.* Inhibitory control was assessed using a computerised version the Stroop interference task (3 blocks of 60 trials each, practice block of 20 trials). In this task, participants must press a key corresponding to the colour a word is printed in as quickly as possible, while making as few errors as possible. *Congruent trials* consisted of colour words that were printed in the corresponding colour (e.g., the word RED coloured in red). In *incongruent trials*, the colour of the colour word was different to the word itself (e.g., the word RED coloured in blue). *Control trials* consisted of a block of colour approximately the size of the colour words. Stimuli were displayed until the participant responded, and the response-stimulus interval was 500ms. The Stroop interference score was calculated as the difference between mean response time of correct responses on incongruent trials and control trials (MacLeod, 2005), where a larger score indicated poorer inhibitory control. Response
times that fell three standard deviations above or below a participant’s mean reaction time per block were deemed to be outliers and were deleted (MacLeod, 2005).

*Stop signal task.* The Stop signal task was included as a second measure of inhibitory control. Each trial began with a fixation cross (+) presented in the centre of the screen for 500ms. After this fixation cross, an image of a left arrow or a right arrow was presented. Participants were required to quickly categorise the content of the picture by pressing the “D” key for a left arrow or the “K” key for a right arrow, counterbalanced across participants. On 25% of trials an auditory tone occurred after a delay, which signified that participants should inhibit their motor response on that trial and wait for the next trial. The stop signal delay was initially set at 250ms and was adjusted dynamically according to participants’ responses using a staircase tracking procedure: when inhibition was either successful or unsuccessful the delay increased or decreased by 50ms respectively. On stop signal trials, responses within the 1500ms timeout period were classed as inhibition errors. The task was split into four blocks: a practice block of 32 trials and three experimental blocks of 64 trials. Participants who inhibited significantly more or less than 50% of the time were removed from analysis as this indicated they were not responding correctly to the stop signal. Inhibitory control was assessed using the mean stop signal reaction time, which was calculated using the subtraction method in which mean stop signal delay is subtracted from the raw mean reaction time for all no-signal trials (Logan, 1994; Verbruggen, Logan, & Stevens, 2008). A greater stop signal reaction time indicated poorer inhibitory control.

*Single adaptive n-back.* The single adaptive n-back using visual stimuli (Jaeggi et al., 2010) was used to assess updating ability. Participants were shown a series of random yellow shapes presented centrally on a black background for 500ms each followed by a 2500ms inter-stimulus interval and were required to respond when the current shape matched the shape presented n positions back in the series. Participants began on the 1-back level and the
level of \( n \) was adjusted after each block according to performance: if less than 3 errors were made, \( n \) increased by 1, while if more than 5 errors were made \( n \) decreased by 1, if 3-5 errors were made, \( n \) stayed the same. The task consisted of 15 blocks of 24 trials. Updating ability reflected the proportion of hits minus false alarms averaged over all \( n \)-back levels, such that higher scores indicated greater updating capacity.

**Automated Operation Span.** The Turner and Engle (1989) OSPAN task required participants to indicate whether a math equation (e.g., \( (1*2) + 1 = 4 \)) was true or false. Following the equation, participants were presented with a letter for 800ms, which was to be recalled. The presentation of equations and letters continued until the set size had been reached for that block and then the recall screen consisting of a 4 x 3 matrix of letters was presented in which participants indicated the letters that had been presented to them in the correct order. Set sizes ranged from 3 – 7 equation-letter presentations, with three blocks of each set size, presented in random order so that participants could not predict the number of items to be recalled. If the participants took more time to solve the math equations than their average time calculated from practice trials plus 2.5 \( SD \), the program automatically moved on and counted that trial as an error. This was to prevent participants from rehearsing the letters when they should be solving the equations. To ensure participants were attempting to solve both the math equations and remember the letters, an 85% accuracy criterion was imposed for math problems. Updating was assessed by OSPAN score which was the sum of all perfectly recalled sets such that if an individual correctly recalled 2 letters in a set size of 2, 4 letters in a set size of 4, and 3 letters in a set size of 5, OSPAN score would be 6 (2+ 4+ 0). A higher OSPAN score indicated greater updating ability.

**Procedure**

The study was conducted entirely online. Following sign up and consent, participants received the link to a survey containing demographic variables and the Dutch Eating
Behaviour Questionnaire. They were then directed to the first two executive function tasks. The next day participants were emailed a link to the remaining tasks and finally, one week later, were emailed a link to a survey containing the eating behaviour questionnaires. The order of executive functioning tasks across the two-day period was counterbalanced across participants to control for the possible influence of order effects. Participants were also instructed to take a five-minute break between executive function tasks to avoid a diminished performance effect on subsequent tasks. All executive function tasks were created by and administered through Inquisit 4 by Millisecond Software, while the survey was administered through LimeSurvey.

**Data Analysis**

Person product correlations were computed to examine the relationships between BMI, eating cognitions, inhibitory control, updating, saturated fat intake and fruit and vegetable consumption. Identical hierarchical regression analyses were conducted to measure the utility of inhibitory control (Step 3) and updating (Step 4) for predicting either saturated fat intake or fruit and vegetable consumption while controlling for BMI and gender (Step 1) and eating-related cognitions (Step 2).

**Results**

**BMI**

BMI ranged from 18.52 to 33.20 ($M = 21.96$, $SD = 3.10$), and 85% of the sample were within the normal BMI range. No participants indicated that they had been either diagnosed in the past or were currently diagnosed with an eating disorder.

**Correlations**

As can be seen in Table 1, BMI was positively correlated with restrained eating such that those of a higher BMI tended to have more restrained eating cognitions. BMI was also correlated with the two eating behaviour measures, such that those with a higher BMI tended
to consume more saturated fat and less fruit and vegetables. All three eating cognitions correlated with saturated fat intake such that those with more restrained eating cognitions ate less saturated fat, and those with higher external and emotional eating cognitions ate more saturated fat. Both measures of inhibitory control were positively correlated with saturated fat consumption such that those with poorer inhibitory control consumed more saturated fat; however, neither measure of updating was correlated with saturated fat intake. Both measures of updating were positively correlated with fruit and vegetable consumption, such that greater updating ability was related to higher consumption of fruit and vegetables. Neither measure of inhibitory control was related to fruit and vegetable consumption nor were any of the eating cognitions.
Table 1. Means, standard deviations, and Pearson’s correlations of BMI, eating cognitions, executive function and behaviour measures of saturated fat intake and fruit and vegetable consumption

<table>
<thead>
<tr>
<th></th>
<th>BMI</th>
<th>RE</th>
<th>XE</th>
<th>EE</th>
<th>STROOP</th>
<th>SST</th>
<th>NBACK</th>
<th>OSPAN</th>
<th>SF</th>
<th>FV</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>1</td>
<td>.191*</td>
<td>-.115</td>
<td>-.049</td>
<td>.075</td>
<td>.016</td>
<td>-.053</td>
<td>-.056</td>
<td>.192*</td>
<td>-.204*</td>
</tr>
<tr>
<td>RE</td>
<td>1</td>
<td>-.008</td>
<td>.146</td>
<td>-.068</td>
<td>-.088</td>
<td>.063</td>
<td>-.078</td>
<td>-.259**</td>
<td>-.179</td>
<td></td>
</tr>
<tr>
<td>XE</td>
<td>1</td>
<td>.554**</td>
<td>.020</td>
<td>-.031</td>
<td>.075</td>
<td>-.064</td>
<td>.206*</td>
<td>.103</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE</td>
<td>1</td>
<td>-.054</td>
<td>-.005</td>
<td>-.120</td>
<td>.039</td>
<td>.210*</td>
<td>.132</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STROOP</td>
<td>1</td>
<td>.237*</td>
<td>.003</td>
<td>-.190*</td>
<td>.300**</td>
<td>-.014</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SST</td>
<td>1</td>
<td>.052</td>
<td>.049</td>
<td>.274**</td>
<td>-.029</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NBACK</td>
<td>1</td>
<td>.216*</td>
<td>.120</td>
<td>.195*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSPAN</td>
<td>1</td>
<td>.029</td>
<td>.280**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF</td>
<td>1</td>
<td>.240**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FV</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SD: 3.102  .824  .604  .778  130.589  55.168  .944  15.625  7.001  2.032

*Notes. BMI = Body mass index; RE = restrained eating; XE = external eating, EE = emotional eating; SST = Stop signal task performance; OSPAN = operation span task performance; *p < 0.05; **p < 0.01.
**Saturated fat consumption**

Gender and BMI accounted for 6% of the variance in saturated fat consumption, although gender was the only significant predictor in this step, with males tending to eat more saturated fat (see Table 2). At step 2, eating cognitions accounted for an additional 14.2% of variance in saturated fat consumption, with both restrained and emotional eating significantly predicting saturated fat. The unique influence of external eating was not significant. At step 3, inhibitory control accounted for an additional 11.8% of variance in saturated fat consumption and both measures were significant predictors of saturated fat consumption. Updating did not account for a significant amount of variance in saturated fat consumption. The final model accounted for 33.6% of the variance in saturated fat intake, with restrained eating, emotional eating and inhibitory control making significant independent contributions while gender remained a marginally significant predictor ($p = .053$).
Table 2: Hierarchical regression analysis for prediction of saturated fat consumption.

<table>
<thead>
<tr>
<th>Step</th>
<th>Predictor</th>
<th>R²</th>
<th>ΔF</th>
<th>df</th>
<th>β</th>
<th>Final β</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GENDER</td>
<td>.060</td>
<td>3.429*</td>
<td>108</td>
<td>-.246*</td>
<td>-.191</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
<td>-.005</td>
<td>.083</td>
</tr>
<tr>
<td>2</td>
<td>RE</td>
<td>.201</td>
<td>6.214**</td>
<td>105</td>
<td>-.277**</td>
<td>-.250**</td>
</tr>
<tr>
<td></td>
<td>XE</td>
<td></td>
<td></td>
<td></td>
<td>.095</td>
<td>.066</td>
</tr>
<tr>
<td></td>
<td>EE</td>
<td></td>
<td></td>
<td></td>
<td>.241*</td>
<td>.284**</td>
</tr>
<tr>
<td>3</td>
<td>STROOP</td>
<td>.319</td>
<td>8.914**</td>
<td>103</td>
<td>.230**</td>
<td>.234**</td>
</tr>
<tr>
<td></td>
<td>SST</td>
<td></td>
<td></td>
<td></td>
<td>.211*</td>
<td>.201*</td>
</tr>
<tr>
<td>4</td>
<td>NBACK</td>
<td>.336</td>
<td>1.232</td>
<td>101</td>
<td>.129</td>
<td>.129</td>
</tr>
<tr>
<td></td>
<td>OSPAN</td>
<td></td>
<td></td>
<td></td>
<td>.008</td>
<td>.008</td>
</tr>
</tbody>
</table>

Notes. BMI = Body mass index; RE = restrained eating; XE = external eating, EE = emotional eating; SST = Stop signal task performance; OSPAN = operation span task performance; overall R² = .336, *p < .05; **p < .01.

**Fruit and vegetable consumption**

As can be seen in Table 3, gender and BMI accounted for 6.8% of the variance in fruit and vegetable consumption; however, BMI was the only significant predictor in this step indicating that those with a higher BMI tended to eat less fruits and vegetables. Eating cognitions at step 2 did not account for a significant proportion of variance in fruit and vegetable consumption, and nor did inhibitory control at step 3. At step 4, updating accounted for an additional 7.6% of the variance in fruit and vegetable consumption; however, only OSPAN but not n-back performance was significant. The final model accounted for 18.2% of the variance in fruit and vegetable consumption, with OSPAN performance making a significant independent contribution, while BMI remained a marginally significant predictor (p = .058).
The aim of this study was to determine which facets of executive function were related to saturated fat intake and fruit and vegetable consumption, while controlling for demographic variables and eating cognitions. As hypothesised, those with a higher inhibitory control capacity consumed less saturated fat; however, contrary to expectations, updating ability was not related to saturated fat consumption. In contrast, updating was related to fruit and vegetable consumption such that those with a higher updating ability consumed more fruit and vegetables and as expected, inhibitory control was not related to fruit and vegetable consumption.

The current results suggest that amongst people with healthy eating intentions, individual differences in inhibitory control capacity predict saturated fat consumption. This is

<table>
<thead>
<tr>
<th>Step</th>
<th>Predictor</th>
<th>R²</th>
<th>ΔF</th>
<th>df</th>
<th>β</th>
<th>Final β</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GENDER</td>
<td>.068</td>
<td>3.941*</td>
<td>108</td>
<td>-.183</td>
<td>-.132</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
<td>-.272**</td>
<td>-.204</td>
</tr>
<tr>
<td>2</td>
<td>RE</td>
<td>.104</td>
<td>1.391</td>
<td>105</td>
<td>-.113</td>
<td>-.127</td>
</tr>
<tr>
<td></td>
<td>XE</td>
<td></td>
<td></td>
<td></td>
<td>-.034</td>
<td>-.030</td>
</tr>
<tr>
<td></td>
<td>EE</td>
<td></td>
<td></td>
<td></td>
<td>.189</td>
<td>.191</td>
</tr>
<tr>
<td>3</td>
<td>STROOP</td>
<td>.105</td>
<td>.105</td>
<td>103</td>
<td>.004</td>
<td>.053</td>
</tr>
<tr>
<td></td>
<td>SST</td>
<td></td>
<td></td>
<td></td>
<td>-.044</td>
<td>-.073</td>
</tr>
<tr>
<td>4</td>
<td>NBACK</td>
<td>.182</td>
<td>4.712*</td>
<td>101</td>
<td>.128</td>
<td>.128</td>
</tr>
<tr>
<td></td>
<td>OSPAN</td>
<td></td>
<td></td>
<td></td>
<td>.225*</td>
<td>.225*</td>
</tr>
</tbody>
</table>

Notes. BMI = Body mass index; RE = restrained eating; XE = external eating, EE = emotional eating; SST = Stop signal task performance; OSPAN = operation span task performance; overall R² = .182, * significant at the .05 level, ** significant at the .01 level.

Discussion

The aim of this study was to determine which facets of executive function were related to saturated fat intake and fruit and vegetable consumption, while controlling for demographic variables and eating cognitions. As hypothesised, those with a higher inhibitory control capacity consumed less saturated fat; however, contrary to expectations, updating ability was not related to saturated fat consumption. In contrast, updating was related to fruit and vegetable consumption such that those with a higher updating ability consumed more fruit and vegetables and as expected, inhibitory control was not related to fruit and vegetable consumption.

The current results suggest that amongst people with healthy eating intentions, individual differences in inhibitory control capacity predict saturated fat consumption. This is
in line with dual process models of self-regulation which suggest that behaviour is governed by two systems: the impulsive and the reflective (Hofmann, Friese, & Wiers, 2008; Strack & Deutsch, 2004). When conflict arises between achieving a goal and engaging in automatic tendencies that thwart goal attainment, these tendencies must be inhibited to successfully carry out goal-directed behaviour. The current results are similar to Honkanen, Olsen, Verplanken, and Tuu (2012) who demonstrated that food related self-control moderated the relationship between attitudes towards unhealthy snacking and behaviour, such that within those with stronger self-control, attitudes towards snacking were more likely to guide behaviour. Similarly, Hofmann et al. (2009) demonstrated that within those with low inhibitory control as measured by the SST, automatic affective reactions to chocolate guided consumption. Therefore, it appears that inhibitory control is necessary in order for individuals to behave in line with their healthy eating goals.

Hofmann et al. (2008) also demonstrated the same relationship between automotive affective reactions and chocolate consumption within those who performed poorly on the OSPAN, suggesting that updating is also required to carry out goal-directed behaviour. Therefore, it was surprising that updating ability did not relate to saturated fat consumption in the current study. Research suggests that updating enables individuals to resist the attentional capture of stimuli at early stages of processing (Friese, Bargas-Avila, Hofmann, & Wiers, 2010). However, strategies which assist goal-directed behaviour once attention has been captured, such as stopping a response to tempting stimuli, may be more relevant to avoiding consumption of foods high in saturated fat. Alternatively, it is possible that updating does not play a direct role in saturated fat consumption, such that it is only predictive amongst those with strong implicit preferences for unhealthy foods. As such, future research should attempt to resolve these inconsistent findings and elucidate the role of updating in saturated fat consumption by considering alternative measures of updating, particularly, those which
include stimuli related to the behavior of interest such as that used by Hege et al. (2013) and Stingl et al. (2012).

Healthy eating involves not only avoiding foods that are high in saturated fat but also the consumption of fruit and vegetables. Limited research has linked the consumption of healthy foods with measures of executive function. As expected, inhibitory control did not play a role in fruit and vegetable consumption. This is consistent with previous research that has failed to find a relationship between executive function and healthy eating (Allan et al., 2011; Collins & Mullan, 2011; Hall, 2011). The current findings are also consistent with a series of studies by Mullan and colleagues that failed to find a relationship between inhibitory control and many health enhancing behaviours including breakfast consumption (Wong & Mullan, 2009), food hygiene (Fulham & Mullan, 2011) and sun protection behaviour (Allom, Mullan, & Sebastian, 2012). It appears that for health enhancing behaviours, which usually require the initiation of a response, inhibitory control is not necessary.

The novel finding that updating predicted fruit and vegetable consumption sheds light on how health enhancing behaviours are successfully carried out. Updating is said to directly support active representations of self-regulatory goals and the associated means by which these goals can be attained (Kruglanski et al., 2002; Miller & Cohen, 2001). It appears that goal representation and maintenance are particularly important for health enhancing behaviours, which require the initiation rather than inhibition of a response. Specifically, a superior updating ability may enable the management of attentional resources, which in turn, results in individuals seeking out opportunities to eat fruit and vegetables. Additionally, it is likely that the role of executive function on the performance of health enhancing behaviours is multifaceted. For example, breakfast consumption has been shown to relate to planning ability (Wong & Mullan, 2009), a complex executive function thought to be linked to both updating and another element of executive function known as shifting (Miyake et al., 2000).
Further, sun protection behaviour has been linked to shifting ability (Allom et al., 2012). Future research should examine how complex executive functions relate to fruit and vegetable consumption.

These results appear to indicate that the predictive utility of executive function constructs differs according to the nature of the behaviour in question. For example, behaviours which involve stopping impulsive responses such as avoiding the consumption of foods high in saturated fat appear to be related to inhibitory control capacity, while behaviours that involve actively seeking out a stimulus, such as consuming the appropriate amount of fruit and vegetables, are conversely related to updating. The results are similar to previous research which has suggested that different types of self-control can distinguish between conceptually distinct behaviours (de Boer, van Hooft, & Bakker, 2011; de Ridder, de Boer, Lugtig, Bakker, & van Hooft, 2011). Through a series of confirmatory factor analyses de Ridder et al. (2011) demonstrated that the Tangney, Baumeister, and Boone (2004) Self-control Scale consisted of two factors: inhibitory self-control and initiatory self-control. It was found that behaviours which required stopping a response, such as alcohol consumption and cigarette smoking, were predicted by inhibitory self-control, while behaviours that required starting a response, such as studying or exercising, were predicted by initiatory self-control (de Ridder et al., 2011). Results from the current study, which suggest that different facets of executive function predict distinct eating behaviours, lend greater support to the notion that self-control is multifaceted. Further, taken together, the results suggest that updating may be conceptually similar to initiatory self-control and thus important in the initiation of goal-directed behaviour. Finally, that eating cognitions were only related to saturated fat consumption, further solidifies the difference between these two behaviours and highlights the importance of understanding not only what leads to the consumption of unhealthy foods but also the consumption of healthy foods.
A strength of the current study was the examination of how executive function relates to healthy eating behaviour, rather than focusing only on unhealthy eating behaviour. Additionally, the inclusion of eating cognitions made it possible to determine the direct effect of executive functions on eating behaviour once known contributors were accounted for. The study was limited in that while participants were recruited on the basis of having the intention to eat healthier, the strength of participants’ intentions was not assessed. It has been established that individual differences in motivation interact with individual differences in executive function to influence eating behaviour (Allan et al., 2011; Honkanen et al., 2012); however, measuring differences in motivation was beyond the scope of the present study. Additionally, the current research was limited by the correlational nature of the data. From these results, it is difficult to determine whether individuals who were better able to carry out their goals did so due to superior executive function or whether healthy eating behaviour led to improvements in executive function. For example, a recent review of cognitive function and the Western diet (high in saturated fat and refined carbohydrates), suggested that the Western diet leads to impaired brain function and also contributes to the development of neurodegenerative conditions (Francis & Stevenson, 2013). It is likely that the relationship between executive function and diet is bidirectional. Studies aiming to train or manipulate executive function in order to improve health behaviour have had moderate success. For example, Houben (2011) demonstrated that participants with initially low inhibitory control who completed a modified SST, which trained the inhibition of responses to high calorie foods, consumed less than those who were not trained to inhibit responses. In terms of updating training, much research has focused on using tasks such as the n-back to improve fluid intelligence; however, evidence suggests that training does not transfer to improvement in intelligence (for review see: Melby-Lervåg & Hulme, 2012; Shipstead, Redick, & Engle, 2012). While updating training may not improve intelligence, conclusions cannot be drawn as
to whether updating training transfers to other outcomes such as healthy eating and this is an avenue worthy of further exploration.

The current results have numerous applications for the improvement of health outcomes via healthy eating behaviour. Specifically, by clarifying the relationship between particular facets of executive function and eating behaviours, interventions aiming to improve these behaviours may benefit from targeting the appropriate element of executive function. As discussed above, evidence suggests that inhibitory control can be augmented to decrease consumption of unhealthy foods (Houben, 2011; Houben & Jansen, 2011). Future research aimed at determining the mechanisms by which such training works may elucidate the efficacy of such interventions. Additionally, programs which combine executive function training with established behaviour change techniques such as implementation intentions (Armitage, 2004) may be particularly useful for the improvement of eating behaviour.

Further, the current results may add to the development of frameworks that allow for greater understanding of similarities and differences between health behaviours; for example, the classification framework put forth by McEachan, Lawton, and Conner (2010) which describes three dimensions on which health behaviours may fall and provides specific predictions about how health behaviours are executed and thus informs behaviour change interventions.

To our knowledge this is the first study to dissociate two related but conceptually distinct health behaviours using several measures of executive function. Taken together these results indicate that superior executive function in one domain does not necessarily lead to the successful performance of all health behaviours and moreover, the particular elements of executive function that are important for one type of behaviour are not necessarily related to another. Specifically, inhibitory control is important for behaviours that require the stopping of a response such as limiting the intake of foods high in saturated fat, while updating is
important for carrying out behaviours that require the initiation of a response such as fruit and vegetable consumption.
References


Jansen, A., Nederkoorn, C., Van Baak, L., Keirse, C., Guerrieri, R., & Havermans, R. (2009). High-restrained eaters only overeat when they are also impulsive. *Behaviour research and therapy, 47*(2), 105-110.


3. DOES INHIBITORY CONTROL TRAINING IMPROVE BEHAVIOR REGULATION? A META-ANALYSIS

Vanessa Allom\textsuperscript{1,2}, Barbara Mullan\textsuperscript{1,2}, Martin Hagger\textsuperscript{2}

\textsuperscript{1}School of Psychology, University of Sydney, Australia
\textsuperscript{2}School of Psychology and Speech Pathology, Curtin University, Australia
Abstract

Inhibitory control training is a behavior change technique where the ability to overrule impulsive reactions is improved in order to regulate behavior consistent with long-term goals. A meta-analysis of 16 studies of inhibitory control training and health behaviors was conducted to determine the effect of training on reducing harmful behaviors, and whether there were moderators of the effect. Moderators tested included training task, behavior, measurement of behavior, and training duration. A small-to-medium effect of training on behavior was found, however, there was significant heterogeneity. Moderation analyses revealed that task, behavior, and measurement type influenced the size of the effect, while training duration did not. The results suggest that inhibitory control training can change behavior and provides elucidation of the optimal task parameters. While training duration did not influence the size of the effect, and the effects did not persist long after training, a systematic examination of these factors is needed.

Keywords: Inhibitory control; training; health behavior; meta-analysis
Does inhibitory control training improve behavior regulation? A meta-analysis

**Inhibitory control & behavior regulation**

Inhibitory control refers to individuals’ capacity for overruling impulsive reactions in order to regulate behavior in line with long-term goals (Miyake et al., 2000; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010). Generally, research findings indicate that the behavior of individuals low in inhibitory control is dominated by impulsive precursors, such as implicit preferences, rather than more reflective precursors, such as intentions or goals (Hofmann et al., 2009). Research has suggested that this construct is particularly important for the regulation of health behaviors, such as dietary fat intake (Hall, 2012) and sleep hygiene (Todd & Mullan, 2013), and addictive behaviors, such as alcohol consumption (Houben & Wiers, 2009) and compulsive gambling (Lawrence, Luty, Bogdan, Sahakian, & Clark, 2009). Specifically, deficits in inhibitory control are associated with poorer eating behavior (Hall, 2012; Hofmann, Friese, & Roefs, 2009) and weight gain (Nederkoorn et al., 2010), and increased alcohol consumption (Houben & Wiers, 2009; Murphy & Garavan, 2011).

**Inhibitory control training**

Current research suggests that inhibitory control can be trained to improve the regulation of behavior. Inhibitory control training typically involves regular practice on a cognitive task said to tax inhibitory control, such as the go/no-go task (GNG; Donders, 1969), or the stop-signal task (SST; Lappin & Eriksen, 1966). Improvement in behavior is usually assessed using a between-participants design wherein participants who are randomly assigned to receive inhibitory control training are expected to demonstrate superior behavior regulation, compared to those assigned to an inert or alternative form of training (Houben & Jansen, 2011; Jones & Field, 2012). Specifically, in GNG training paradigms, participants are required to respond as rapidly as possible to a neutral set of stimuli while withholding responses to a set of stimuli representing the target behavior. Consistent pairings of the no-go
response with target stimuli facilitates the retrieval of no-go-target stimuli associations and results in improved inhibition of responses to target stimuli (Spierer, Chavan, & Manuel, 2013). For example, Houben, Nederkoorn, Wiers, and Jansen (2011) used a GNG with alcohol-related stimuli in order to reduce alcohol consumption. In the training condition, no-go stimuli were consistently paired with alcohol-related stimuli, and go stimuli were consistently paired with neutral stimuli. In the control condition, go stimuli were consistently paired with alcohol-related stimuli, and no-go stimuli were consistently paired with neutral stimuli. The training condition reported less alcohol consumption after training, compared to the control condition, suggesting that an association between alcohol stimuli and a no-go response had been established and that this transferred to reductions in alcohol consumption.

In SST training paradigms, participants are instructed to categorize both target stimuli and neutral stimuli as rapidly as possible. However, on a proportion of trials the stop-signal is presented after target stimuli and participants are required to inhibit their responses. In this way, an association between target stimuli and the stop response is established. In the control condition, stop-signals are not consistently paired with a particular category of stimuli, or are not presented at all. For example, one study aimed to improve the inhibition of responses to high-calorie foods and therefore paired high-calorie food items with a stop-signal (Houben, 2011). This was in comparison to a condition in which stop-signals were never paired with high-calorie food items. Participants who received inhibitory control training consumed significantly less high-calorie food during a pseudo taste test administered immediately after training, compared to those in the control condition. This suggests that establishing an association between unhealthy food and a stop response results in a reduction in consumption of unhealthy foods.

While numerous inhibitory control studies have been carried out with varying success, in terms of producing differences in health behavior, few studies have attempted to ascertain
the mechanism responsible for such differences. According to a dual-systems account of health behavior (Hofmann, Friese, & Strack, 2009; Strack & Deutsch, 2004), behavior can be modified by either: changing impulsive tendencies, improving the ability to self-regulate, or by changing the reflective system (Friese, Hofmann, & Wiers, 2011). Preliminary evidence suggests that GNG training improves health behavior by changing impulsive tendencies. For example, Houben, Havermans, Nederkoorn, and Jansen (2012) employed an implicit association task (IAT; Greenwald, McGhee, & Schwartz, 1998), and another measure of inhibitory control (the SST), and demonstrated that GNG training reduced alcohol consumption by devaluation of the alcohol-related stimuli, rather than by increased inhibitory control, suggesting that GNG training results in a decrease in the influence of impulsive processes, rather than an increase in the ability to self-regulate. This is in contrast to mechanistic explanations regarding the effects of SST training, where it has been suggested that SST training improves health behavior by strengthening the ability to self-regulate. Houben (2011) found that individuals with low baseline inhibitory control ability benefited from SST training, while individuals with high baseline inhibitory control ability did not. This suggests that SST training improves behavior by strengthening inhibitory control; however, as no additional measure of response inhibition was included in this study, it is not known whether this assumption is accurate.

Inhibitory control training appears to result in differences in health behavior between trained and non-trained participants; however, the size and nature of the effect is not known. Namely, the above discussion regarding differences between training paradigms, and potential mechanisms responsible for differences in health behavior, reveals that there are a number of potential moderators that may influence the relationship between inhibitory control training and behavioral regulation.

*Potential moderators of training effect*
**GNG versus SST.** As described above, the two training paradigms differ in that in the GNG, the go response is consistently inhibited for all members of a certain category, while in the SST the ‘go’ response does not need to be inhibited for all members of a certain category, only for a certain proportion. It was suggested that the mechanisms by which these two paradigms influence health behavior may differ, such that GNG training improves health behavior by decreasing implicit attitudes towards the target health behavior (Houben et al., 2012), whereas SST training may improve inhibitory control (Houben, 2011). Examining whether the effectiveness of these training paradigms differs may indicate the efficacy of particular tasks used to influence health behavior, and the mechanism by which these tasks influence behavior.

**Behavior-specific versus neutral training task.** Both the GNG and the SST can be tailored to train inhibitory control in response to a group of stimuli associated with a particular behavior. For example, if a reduction in alcohol consumption is the goal, the GNG may be tailored to include alcohol-related stimuli that are consistently associated with no-go stimuli. However, several studies have also utilized an inhibitory control task with neutral stimuli (Guerrieri et al., 2012; Verbruggen, Adams, & Chambers, 2012; Verbruggen et al., 2013), wherein it is hypothesized that training of a general inhibitory control mechanism is sufficient to improve behavior regulation. While it is likely that the effect of training is larger when behavior-relevant stimuli are used in training tasks, as a specific association between the no-go/stop response and the target behavior is being established, a comparison of the effect of behavior-specific versus neutral training will help establish the efficacy of using tailored tasks.

**Training duration.** Within the inhibitory control training literature, one session of training is typically employed (Bowley et al., 2013; Houben et al., 2012; Jones & Field, 2012; Veling, Aarts, & Papies, 2011); however, the number of trials that a training session involves differs
across studies. Currently there is no direct evidence that longer training sessions are more beneficial. Additionally, it may be the case that a point exists at which the benefits of training plateau and no new gains are achieved despite further training. Therefore, it is worthwhile examining how training duration, as reflected in the number of task trials, influences behavior regulation, particularly to establish parsimonious interventions.

*Type of health behavior.* It is possible that the effectiveness of inhibitory control training will differ according to the characteristics of the target health behavior. For example, research has demonstrated a stronger relationship between inhibitory control and health risk behaviors, such as snack consumption, compared to health enhancing behaviors, such as fruit and vegetable consumption (Collins & Mullan, 2011; Hall, 2012). Additionally, McEachan, Lawton, and Conner (2010) offer a framework for classifying and predicting health-related behaviors based on the unique characteristics of the behavior; namely, the effort required to perform the behavior, the frequency with which performance is required, and the tangibility of the impact of performing the behavior, suggesting that not all health behaviors have the same determinants. Therefore, inhibitory control training may produce different results simply based on the type of health behavior that is being targeted.

*Behavior measurement.* A methodological concern that may account for differences in effect sizes across studies is the way in which behavior is measured. While self-report measures may be subject to reporting bias, they may offer a more externally valid assessment of behavior than laboratory-based measures such as pseudo taste tests (Smyth et al., 2001), which have been used to measure alcohol and food consumption post-training (Bowley et al., 2013; Houben, 2011; Jones & Field, 2012; Nagy, 2012). Determining whether training effects differ based on how behavior is measured may elucidate the true nature of the training effect.
Longevity of training effect. If inhibitory control training does induce improved behavioral regulation, it is important to determine the consistency of these effects over time. While previous research has demonstrated improvements in behavioral regulation when behavioral measures are administered immediately post-training (Houben, 2011; Verbruggen, Adams, & Chambers, 2012), studies that have measured behavior up to a week post-training, have produced both significant differences in health behavior outcomes (Houben et al., 2012), and non-significant results (Bowley et al., 2013; Jones & Field, 2012). Given the lack of conclusive evidence regarding the longevity of the inhibitory control training effect on health behavior, it is important to examine the extent to which the effect of training diminishes over time in a cumulative analysis correcting for methodological artefacts. This may assist in resolving the nature of the effect.

Present analysis

Given the psychological consequences and health risks of engaging in behaviors such as compulsive gambling, unhealthy eating, and excessive alcohol consumption, there is a need to establish the efficacy of techniques designed to reduce such behaviors. This article makes a unique contribution to knowledge of behavior change and inhibitory control by attempting to determine the size and consistency of the effect of inhibitory control training on reducing harmful behaviors while correcting for study precision. A secondary aim is to determine the nature of the effect by examining several potential moderators that might account for any heterogeneity in the training effect. Determining whether extraneous variables moderate the effect may assist in the development of effective intervention strategies to promote better regulation of health behaviors.

We acknowledge that inhibitory control is a multifaceted construct comprised of several similar yet distinct inhibitory processes (Friedman & Miyake, 2004), including response inhibition, cognitive inhibition, and interference control (Gray & McNaughton,
The current review will focus exclusively on response inhibition; the suppression of actions that interfere with goal-directed behavior. This is due to the nature of the tasks used to assess and train this inhibitory process (i.e., GNG and SST). These tasks directly and uniquely demand response inhibition whereas other inhibitory control tasks, including the Flanker and the Stroop, demand other elements of inhibition (Spierer et al., 2013). In addition, research aiming to change behavior by training of self-control will not be considered for similar reasons (e.g., Muraven, 2010; Oaten & Cheng, 2006). Specifically, self-control training involves modifying an element of behavior typically for a two-week period, such as maintaining the correct posture. While this action would demand inhibitory control, it is unclear whether other processes are also influencing behavior change.

**Method**

**Information sources and search strategy**

A systematic literature search was conducted of electronic databases including PsycINFO, Medline, Scopus, and ProQuest Dissertations. The search period was from 1990 up to and including January 2014. The search terms used were: (go nogo OR go no-go OR stop signal OR stop-signal OR response inhibition OR inhibitory control) AND (training OR intervention OR modif*). Searches were limited to human studies, English language publications, and adult populations. In addition, reference sections of retrieved articles were examined, as were the reference sections of key narrative review articles of response inhibition studies (Jones, Christiansen, Nederkoorn, Houben, & Field, 2013; Spierer et al., 2013). Finally, key authors and researchers in the field were contacted for any additional unpublished studies and data sets.

**Inclusion and exclusion criteria**

To be included in the analysis, studies needed to (1) include at least one session of SST or GNG task training; (2) adopt a randomized control design; (3) include a behavioral outcome
measure; (4) contain sufficient statistical information to compute an effect size such as cell means and standard deviations, or F ratios, or t-statistics. When the relevant statistics were not reported for otherwise eligible studies, authors were contacted to obtain the necessary information.

There were no restrictions on the nature of behavior measurement (i.e., self-report or objective behavior), or publication status (i.e., available unpublished data were included). Studies that included two interacting intervention techniques in a single condition using a non-factorial design (e.g., GNG training and diary keeping) were also excluded. Non-experimental studies that used inhibitory control tasks to predict health outcomes or vice-versa were also excluded. Studies which included unsuitable measures of behavioral outcomes, such as those which used the same task or stimuli to assess transfer to behavior, were also excluded.

**Information extracted and meta-analytic strategy**

Means and standard deviations of each intervention condition’s performance on behavioral outcomes were extracted when such information was provided in the manuscript. However, when unavailable, authors were contacted to provide this information. Where possible, pre and post measures of behavioral outcomes were extracted and effect sizes controlling for pre-scores were calculated. All information was entered into Excel spread sheets by two of the authors. Data sets for two studies eligible for inclusion, but with insufficient data to compute effect size, could not be obtained through direct contact with the authors (Guerrieri et al., 2012; Guerrieri et al., 2009). Additionally, effect sizes for the influence of training on one outcome measure could not be obtained from one study (Nagy, 2012).

Comprehensive Meta-Analysis v. 2.0 was used for calculating effect sizes and conducting all analyses including examining publication bias, heterogeneity, and moderation. The effect size metric employed in the current analysis was Cohen’s d (Cohen, 1988), which
represents the standardized mean difference score for experimental and control conditions. Although a systematic literature search was conducted, a random effects model was used in order to control for the possibility that relevant articles were missed (Borenstein, Hedges, & Rothstein, 2007). A random effects model is also recommended when samples across studies are heterogeneous, as was the case in the included studies (DerSimonian & Laird, 1986).

For each effect size a 95% confidence interval (CI95) was calculated, and Cochrane’s \( Q \) and \( I^2 \) statistics were used to explore heterogeneity (Huedo-Medina, Sánchez-Meca, Marin-Martínez, & Botella, 2006). \( Q \) assessed the presence of heterogeneity; if \( Q \) is statistically significant, heterogeneity is present. \( I^2 \) expressed heterogeneity as a percentage of the total variation across the included studies. \( I^2 \) values up to 25% indicated low heterogeneity, up to 50% indicated moderate heterogeneity, and up to 75% or higher indicated high heterogeneity (Higgins, Thompson, Deeks, & Altman, 2003). A moderator analysis was conducted in a mixed-effects model. This model generates information about the extent to which moderators influence the true effect sizes (Hunter & Schmidt, 2000).

**Moderator Coding**

**GNG versus SST.** We tested whether the type of inhibitory control task influenced the effectiveness of training. Studies were categorized into those that adopted either GNG or SST as the training treatment. Tasks requiring participants to withhold a response to all members of a category was categorized as having used a GNG task. Tasks requiring participants to withhold responding to a proportion of stimuli within a category were categorized as having used an SST. We did not differentiate the type of stop-signal used in the SST (i.e., tone versus visual).

**Behavior-specific versus neutral training task.** Tasks that included stimuli related to the target behavior were coded as behavior-specific training tasks and tasks that used neutral
stimuli were categorized as neutral training tasks. If studies included both types of tasks as separate conditions, and compared the performance of these conditions to the same control condition, only the behavior-specific and control comparison was included in order to maintain independence of effect sizes. If studies included a condition in which participants were trained on both behavior-specific and neutral stimuli concurrently, comparisons between this condition and behavior-specific only inhibition conditions were not included due to potential confounds between behavior-specific and neutral inhibition training. Finally, if the inhibitory control training condition was compared to a non-standard control condition, these comparisons were not included due to a lack of consistency across these additional control conditions.

_Type of task._ There was overlap between type of training task and behavioral specificity of training task in that no studies included a neutral GNG task. Therefore, a moderator variable was created that incorporated both of these elements. Studies were coded as using a GNG, an SST-specific, or an SST-neutral training task.

_Training duration._ In order to assess whether intensity of training influenced behavioral outcomes, a meta-regression was conducted with number of trials entered as a continuous predictor of the inhibitory control training effect size.

_Type of health behavior._ A moderator analysis was conducted to determine whether the effect of inhibitory control training on behavioral outcomes differed according to the type of behavior that was targeted. Originally, behaviors were to be categorized into health risk or health enhancing behaviors; however, no included studies attempted to improve a health enhancing behavior. As such, behaviors were categorized according to type of health risk behavior: unhealthy eating, alcohol use, and gambling.
Objective versus non-objective. The measures used to assess differences in behavior were generally objective or subject to bias. Objective measures included laboratory-based taste tests or choice tasks. Non-objective measures were primarily self-report. In one study, participants were given a small bag of palatable food to take home and return the next day after consuming as much or as little of the food as they liked (Veling et al., 2011). As this measure was subject to confound; for example, other individuals may have consumed the contents of the bag, this was considered a non-objective measure.

Longevity of training effect. A moderator variable was created to assess the time at which differences in behavior were assessed. If measurement took place immediately after training this was categorized as immediate-assessment, while all other time frames were considered post-assessment. This ranged from one day to one week.

Measurement of behavior. There was overlap between how and when behavior was assessed in that immediately administered measures tended to be laboratory-based, whereas post-assessment measures tended to be self-report. Therefore, these two moderators were combined into one moderator that indicated both of these elements. Studies were categorized as immediate-objective, post-objective or post-non-objective.

Risk of Bias
An effort was made to include unpublished studies and datasets, as including only published studies risks inflation of effects due to significant results potentially being more likely to be published (Hopewell, McDonald, Clarke, & Egger, 2007). We also made concerted efforts to track down unreported effect sizes. Furthermore, when data used to compute effect sizes such as means, standard deviations, or sample sizes were not reported in published articles, the authors were contacted in order to again avoid potential inflation. Finally, we also computed the fail-safe N (Rosenberg, 2005), to estimate how many potential effects may be required to
reduce the overall averaged corrected effect size to a trivial size. However, the fail-safe N has been shown to be fallible in detecting potential bias in effect sizes (Thornton & Lee, 2000). In fact, it is important to control for ‘small study’ effects, which may reflect a tendency for low-powered small studies to be included in published data sets. Such effects may be indicative of publication bias (Sterne, Egger, & Smith, 2001). This can be detected by examining the plot of the effect size against study precision, that is, the reciprocal of the standard error. The distribution should reflect a ‘funnel’ shape, such that larger studies appear close to the true effect size and smaller, and therefore more imprecise, studies fall further away and should be evenly distributed. Bias is present if values are not evenly distributed within the funnel or fall outside the funnel shape. We computed funnels for the effect sizes in the current study and moderator subgroups. We also applied Duval and Tweedie’s (2000) Trim and Fill procedure to control for ‘small study’ effects in which studies with disproportionately large effects with small sample sizes that are not evenly distributed, or fall outside the funnel plot, are removed and ‘filled’ with hypothetical studies to revolve the uneven distribution. To the extent that the averaged corrected effect size remains unchanged after the application of the trim and fill, we have evidence that the sample of studies is unaffected by publication bias.

**Results**

The literature search identified 16 studies, within 12 articles, that met the inclusion criteria; therefore, 16 independent tests of the training effect were included in the meta-analysis. Figure 1 shows the entire study selection process.
Figure 1. Flow diagram for the search and inclusion criteria for studies in the meta-analysis. Adapted from (Moher, Liberati, Tetzlaff, & Altman, 2009).

Characteristics of included studies
Table 1 displays the studies included in the meta-analysis and the characteristics of the studies. The mean sample size within the datasets was 61. Two studies included only a neutral inhibitory control training task (Verbruggen et al., 2012; Verbruggen et al., 2013). A further two included both a behavior-specific condition and a neutral task training condition (Jones & Field, 2012; Nagy, 2012). In order to maintain independence of effect sizes, only the effect size for the behavior-specific and control comparison was extracted and entered into the analysis. Two studies included a condition in which participants were trained on both behavior-specific and neutral stimuli concurrently (Houben, 2011; Houben & Jansen, 2011). In addition, one study included a previously-established intervention strategy as a secondary control condition (Bowley et al., 2013), namely, the Brief Alcohol Intervention (Hallett, Maycock, Kypri, Howat, & McManus, 2009), while another included a no-training condition in which participants immediately carried out the outcome measures (Verbruggen et al., 2012). Comparisons between inhibitory control training and these control conditions were not included due to the small number of studies utilizing non-standard control conditions. Finally, one study measured behavior using a task that included the same stimuli that participants were trained on, and was therefore not included due to the questionable generalizability of the findings (Veling et al., 2013a).

Three different types of behaviors were reported: alcohol consumption, unhealthy food consumption and gambling behavior. The majority of studies used one measure of health behavior to assess the effect of training on health behavior. Particularly, several studies used a laboratory-based measure. The most frequently used laboratory-based measure was a pseudo taste test administered immediately after the training session. While some studies used both a laboratory-based and a self-report measure of health behavior, this was confined to the studies examining the effect of training on alcohol consumption (Bowley et al., 2013; Houben et al., 2011; Jones & Field, 2012; Nagy, 2012), where both a pseudo taste test and the
Timeline Follow-back questionnaire (Sobell & Sobell, 1992) were used to assess differences in alcohol consumption between trained and non-trained conditions. For these studies, the mean of the effect size was taken. These studies and one more (Houben et al., 2012), utilized a pre-post design to assess change in alcohol consumption. For these studies, the effect size was calculated after taking into account baseline alcohol consumption, rather than using post-training scores only.
### Table 1

*Effect Sizes and Characteristics of Studies Included In the Meta-Analysis*

<table>
<thead>
<tr>
<th>Study</th>
<th>Task</th>
<th>Behavior</th>
<th>Training condition</th>
<th>Control condition</th>
<th>Sessions; trials in each session</th>
<th>Behavioral outcome &amp; result</th>
<th>Participants</th>
<th>(d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowley et al. (2013)</td>
<td>GNG; behavior-specific</td>
<td>Alcohol consumption</td>
<td>Beer no-go</td>
<td>Beer go</td>
<td>1; 80</td>
<td>Less beer consumed in taste test, self-report alcohol consumption</td>
<td>59</td>
<td>.32a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>drink beer regularly and have a preference for beer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houben et al. (2012)</td>
<td>GNG; behavior-specific</td>
<td>Alcohol consumption</td>
<td>Beer no-go</td>
<td>Beer go</td>
<td>1; 320</td>
<td>Lower self-reported alcohol consumption</td>
<td>57 heavy drinkers; have a preference for beer</td>
<td>.51*b</td>
</tr>
<tr>
<td>Houben (2011)</td>
<td>SST; behavior-specific; within subjects</td>
<td>Eating behavior</td>
<td>snacks paired with stop</td>
<td>snacks paired with go</td>
<td>1; 288</td>
<td>Snacks taste test</td>
<td>29 female undergraduates; positive attitudes/liking towards crisps, nuts and chocolate</td>
<td>.45</td>
</tr>
<tr>
<td>Houben and Jansen (2011)</td>
<td>GNG; behavior-specific</td>
<td>Eating behavior</td>
<td>chocolate no-go</td>
<td>chocolate go</td>
<td>1; 320</td>
<td>Chocolate taste test</td>
<td>63 female undergraduates; trait chocolate lovers</td>
<td>.54</td>
</tr>
<tr>
<td>Study</td>
<td>Task</td>
<td>Condition</td>
<td>Instructions</td>
<td>Participants</td>
<td>Consumption Measure</td>
<td>Effect Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
<td>-----------</td>
<td>--------------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houben, Nederkoorn, et al. (2011)</td>
<td>GNG; behavior-specific</td>
<td>Alcohol consumption</td>
<td>beer no-go</td>
<td>Less beer consumed in taste test; lower self-reported alcohol consumption</td>
<td>52 heavy drinkers; have a preference for beer</td>
<td>.59***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jones and Field (2012; Study 1)</td>
<td>SST; behavior-specific</td>
<td>Alcohol consumption</td>
<td>alcohol paired with stop signal (go)</td>
<td>Less alcohol consumed in taste test; self-report alcohol consumption</td>
<td>90 staff and students; heavy social drinkers; liking of beer</td>
<td>.26*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nagy (2012)</td>
<td>SST; behavior-specific</td>
<td>Alcohol consumption</td>
<td>alcohol paired with stop signal</td>
<td>Alcohol taste test; self-report alcohol consumption</td>
<td>45 heavy drinkers</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>van Koningsbruggen et al. (2013; Study 1)</td>
<td>GNG; behavior-specific</td>
<td>Eating behavior</td>
<td>sweets no-go</td>
<td>Less food serving behavior</td>
<td>89 undergraduates</td>
<td>.78*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>van Koningsbruggen et al. (2013; Study 2)</td>
<td>GNG; behavior-specific</td>
<td>Eating behavior</td>
<td>sweets no-go</td>
<td>Less snacks dispensed in a virtual snack dispenser</td>
<td>88 undergraduates</td>
<td>.76*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Task</td>
<td>Condition</td>
<td>Behavior</td>
<td>Design</td>
<td>Sample Size</td>
<td>Results</td>
<td>Participants</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
<td>-----------</td>
<td>----------</td>
<td>--------</td>
<td>-------------</td>
<td>---------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>Veling et al. (2011; Study 2)</td>
<td>GNG; behavior-specific</td>
<td>Eating behavior</td>
<td>sweets no-go</td>
<td>sweets go</td>
<td>1; 72</td>
<td>Less candy consumption (take home bag)</td>
<td>46 undergraduates .27</td>
<td></td>
</tr>
<tr>
<td>Veling, Aarts, and Stroebe (2013b; Study 1)</td>
<td>SST; behavior-specific</td>
<td>Eating behavior</td>
<td>snacks no-go</td>
<td>snacks go</td>
<td>1; 96</td>
<td>Fewer unhealthy choices</td>
<td>79 adults/community sample .72*</td>
<td></td>
</tr>
<tr>
<td>Veling et al. (2013b; Study 2)</td>
<td>SST; behavior-specific</td>
<td>Eating behavior</td>
<td>snacks no-go</td>
<td>snacks go</td>
<td>1; 96</td>
<td>Fewer unhealthy choices under cognitive load</td>
<td>44 adults/community sample .54*</td>
<td></td>
</tr>
<tr>
<td>Verbruggen et al. (2012; Study 2)</td>
<td>SST; neutral</td>
<td>Gambling</td>
<td>stop response</td>
<td>double response- go trials and push space bar</td>
<td>1; 720</td>
<td>Lower betting score</td>
<td>81 adults/community sample .90**</td>
<td></td>
</tr>
<tr>
<td>Verbruggen et al. (2012; Study 3)</td>
<td>SST; neutral</td>
<td>Gambling</td>
<td>stop response</td>
<td>double response- go trials and push space bar</td>
<td>1; 840</td>
<td>Lower betting score</td>
<td>54 adults/community sample .60*</td>
<td></td>
</tr>
<tr>
<td>Verbruggen et al. (2013; Study 1)</td>
<td>SST; neutral</td>
<td>Gambling</td>
<td>stop response</td>
<td>double response- go trials and push space bar</td>
<td>1; 840</td>
<td>betting score</td>
<td>59 adults/community sample -.23</td>
<td></td>
</tr>
</tbody>
</table>
Verbruggen et al. (2013; Study 2) conducted a stop-signal task (SST) with neutral and gambling-related stimuli. The stop response was double-stimulus with go-trials and push-space-bar trials. The interval between Session 1 and Session 2 was 24h. A total of 48 undergraduates participated in this study. The betting score was measured, and the mean was -.43 for the neutral stimuli condition.

**Notes:** Significant results are presented in boldface; non-significant results are presented with strikethrough; trend in italics; GNG = go/no-go task; SST = stop-signal task. * p < .10; ** p < .05.

- Combined effect size from self-report and laboratory-based measure.
- Effect size calculated controlling for pre-scores on self-report measure.
- Study also included additional control condition: Brief Alcohol Intervention.
- Study also included control condition in which behavior specific and neutral stimuli were training concurrently.
- Study also included inhibitory control training condition with neutral stimuli.
- Study also included a no-training condition in which outcome measures were immediately assessed.
Overall training effect

The averaged corrected standardized mean difference for response inhibition training on health behavior was $d^* = 0.438$, $CI_{95} = [0.267, 0.609]$, $p < .001$. This represents an effect that falls between the small (0.20) and medium (0.50) effect size guidelines proposed by Cohen (1988). Two of the 16 effect sizes were negative in valence, indicating that training produced a detrimental effect on behavioral outcomes. Tests for heterogeneity indicated that there was substantial heterogeneity in the effect size across studies that was unattributed to sampling error, $Q(15) = 23.041$, $p = .038$; $I^2 = 34.99\%$, indicating the likely presence of extraneous moderators. In addition, the effect size could also be considered non-trivial given that the confidence interval did not include zero. The fail safe sample-size ($N_{FS} = 147$) exceeded the suggested cut off value, indicating that it was highly unlikely that sufficient studies with null effects exist which, if included, could reduce the size of the effect. However, inspection of funnel plot and application of Duval and Tweedie’s (2000) Trim and Fill method to correct for small-study bias suggested that four studies were missing on the left side of the mean effect size. This indicated that the included small-studies, which fell to the right of the mean, may be inflating the effect size. Using the Trim and Fill method to adjust for small-study bias, the imputed point estimate is $d^* = 0.335$, $CI_{95} = [0.166, 0.503]$, $p < .001$.

Moderator analyses

GNG versus SST. The effect of training on health outcomes did not differ significantly according to whether the GNG, $d^* = 0.534$, $CI_{95} = [0.327, 0.741]$, $p < .001$, or the SST, $d^* = 0.365$, $CI_{95} = [0.081, 0.649]$, $p = .012$, was used as the training task. However, while the effect of GNG training on behavioral outcomes was homogenous, $Q(6) = 2.466$, $p = .872$, $I^2 = 0.00$, the effect of SST training on behavioral outcomes was effected by substantial heterogeneity, $Q(8) = 19.061$, $p = .015$, $I^2 = 58.03\%$, indicating that within studies using the SST task, further factors may account for the variability in the effect sizes.
Behavior-specific versus neutral-training task. The effect of training on health outcomes, when the task was tailored to the specific behavior, resulted in a medium effect of $d^r = 0.515$, CI$_{95} = [0.357, 0.673]$, $p < .001$. However, the effect of training using a neutral response-inhibition task was not significant, $d^r = 0.211$, CI$_{95} = [-0.409, 0.831]$, $p = .505$. While the effect of behavior-specific training was homogenous, $Q(11) = 3.855$, $p = .974$, $I^2 = 0.00\%$, the effect of neutral training was significantly heterogeneous, $Q(3) = 15.422$, $p = .001$, $I^2 = 80.55\%$.

Type of task. Examining the effect of training according to both the type of task, and whether the task was tailored or neutral, revealed that both the tailored version of the GNG, $d^r = 0.534$, CI$_{95} = [0.327, 0.741]$, $p < .001$, and the tailored version of the SST, $d^r = 0.488$, CI$_{95} = [0.244, 0.733]$, $p < .001$, yielded significant effects for improvement in behavioral outcomes. In addition, both these sets of effect sizes were homogenous, $Q(6) = 2.466$, $p = .872$, $I^2 = 0.00$; and $Q(4) = 1.310$, $p = .860$, $I^2 = 0.00$, respectively. However, the effect of neutral SST training on health behavior did not appear to be significant, $d^r = 0.211$, CI$_{95} = [-0.409, 0.831]$, $p = .505$, but was significantly heterogeneous, $Q(3) = 15.422$, $p = .001$, $I^2 = 80.547$, indicating that other factors may account for the variance in effect sizes within this category of tasks.

Training duration. Length of training, indexed as number of trials, was treated as a continuous moderator of the inhibitory control training effect. A linear regression analysis was conducted, with the training effect size as the dependent variable and number of trials as an independent continuous predictor. The analysis did not yield a significant effect for task duration on the training effect ($\beta = -.0004$, $z = -1.569$, $p = .117$).

Type of health behavior. Examining the effect of training according to each type of behavior revealed that training produced significant effects for both improvement in alcohol
consumption, $d^* = 0.451$, CI$_{95} = [0.231, 0.689]$, $p < .001$, and eating behavior, $d^* = 0.566$, CI$_{95} = [0.354, 0.777]$, $p < .001$. The effect of training on alcohol consumption appeared to yield an effect size between the small-to-medium guideline, while the effect of training on eating behavior appeared to yield a medium effect. However, as the confidence intervals overlapped, these effect sizes were not substantively different. In addition, both sets of effect sizes for alcohol consumption, $Q(4) = 0.997$, $p = .910$, $I^2 = 0.00$, and eating behavior, $Q(6) = 2.359$, $p = .884$, $I^2 = 0.00$, were sufficiently homogenous. The confidence interval for the effect of training on gambling outcomes included the value of zero; therefore, this effect is considered trivial in size and it is questionable whether it is a real effect at all, $d^* = 0.211$, CI$_{95} = [-0.409, 0.831]$, $p = .505$. There was also significant heterogeneity within the effect sizes yielded from the gambling studies, $Q(3) = 15.422$, $p = .001$, $I^2 = 80.547$. However, as the confidence intervals overlapped, this effect was not substantially smaller than that obtained for the studies on alcohol consumption or eating behavior.

**Objective versus non-objective.** It appeared that training produced similar effects on behavior assessed through objective measures, $d^* = 0.454$, CI$_{95} = [0.182, 0.727]$, $p = .001$, compared to non-objective measures, $d^* = 0.450$, CI$_{95} = [0.153, 0.747]$, $p = .003$. While non-objective measures appeared to produce homogenous effect sizes, $Q(2) = 0.530$, $p < .001$, $I^2 = 0.00\%$, objective measures appeared to be significantly heterogeneous, $Q(9) = 21.687$, $p = .010$, $I^2 = 58.50\%$.

**Longevity of training effect.** The time at which behavior was measured appeared to influence the size of the effect of training on behavioral outcomes. Behavior measured immediately resulted in a medium effect size of $d^* = 0.630$, CI$_{95} = [0.423, 0.838]$, $p < .001$, with confidence intervals that excluded zero. Whereas behavior measured at a later time point was substantially smaller and included zero raising the question as to whether this is a true effect,
$d^r = 0.230, \text{CI}_{95}\% = [-0.145, 0.605], p = .228$. While the effect size for immediately measured behavior was homogenous, $Q(6) = 1.893, p = .929, I^2 = 0.00\%,$ the effect size for behavior measured at a later time point was not, $Q(5) = 13.944, p = .016, I^2 = 64.14\%.$

**Measurement of behavior.** Examining the effect size based on when and how behavior was measured revealed that laboratory-based tasks administered immediately after training yielded larger effect sizes, $d^r = 0.646, \text{CI}_{95}\% = [0.450, 0.842], p < .001; Q(7) = 2.033, p = .955, I^2 = 0.00\%,$ than that administered at a later point in time, $d^r = -0.317, \text{CI}_{95}\% = [-0.699, 0.064], p = .103; Q(1) = 0.244, p = .621, I^2 = 0.00\%,$ as indicated by the lack of overlap in confidence intervals. Self-report measures administered at a later point in time yielded a small-to-medium effect size, $d^r = 0.450, \text{CI}_{95}\% = [0.153, 0.747], p = .003; Q(2) = 0.530, p = .767, I^2 = 0.00\%.$ While both immediately administered laboratory-based measures of behavior and self-report measures were non-zero according to confidence intervals, the effect size for laboratory measures administered at a later time point was not, raising questions as to whether this is a true effect. All effect sizes were homogenous.

**Discussion**

The aim of this meta-analysis was to conduct a quantitative cumulative analysis of studies examining the effect of inhibitory control training on health-related behavioral outcomes. Our main purpose was to establish the size of the effect across studies, and whether it was non-trivial, after correcting for study precision using meta-analytic techniques. We were also interested in whether task parameters and methodological characteristics influenced the size and consistency of the training effect. The meta-analysis of the overall training effect produced an effect size between the small-to-medium guideline effect sizes proposed by Cohen (1988). Confidence intervals about the effect did not include the value of zero indicating that the effect size across studies was non-trivial and likely to be a ‘real’ effect.
However, the effect size was subject to substantial heterogeneity, indicating unexplained variance in the effect size across studies and the presence of extraneous moderators.

Moderation analyses revealed that training that used either a behavior-specific GNG or a behavior-specific SST produced significant medium effect sizes. However, studies that employed training on neutral-stimuli tasks did not produce non-zero effect sizes, questioning the propensity of these tasks to produce effects. In general, training that utilized the SST did not appear to differ from training that utilized the GNG, suggesting that if these tasks produce improvements in behavior via different mechanisms, these mechanisms do not differ in their effectiveness. Further, it appeared that the length of the training session did not influence the size of the training effect. In terms of whether inhibitory control training was more beneficial to a particular behavior, analyses revealed non-zero effects for both eating behavior and alcohol consumption, but not for gambling behavior. Outcomes that were measured immediately after training appeared to produce medium-sized non-zero effects, whereas those measured at a later time point were not significant. When considering the method of measurement, immediately administered objective measures produced a medium-sized effect, whereas objective measures that were administered a least one day after training did not result in a non-zero effect. Finally, non-objective measures, which were all administered at least one day after training, resulted in a small-to-medium sized effect.

**Type of task**

Inhibitory control training that utilized either a behavior-specific GNG or a behavior-specific SST produced medium effect sizes, which were homogenous. This suggests that interventions aiming to improve engagement in harmful behaviors through inhibitory control training can employ either of the two tasks. Extrapolating these results, it may be inferred that both means of improving health behavior, as suggested by dual-systems approaches: reducing the influence of the impulsive system or strengthening self-regulation (Friese et al., 2011), may
result in comparable benefits. However, due to the limited number of studies that included additional measures to assess these potential mechanisms, it was not possible to test this assumption. In order to address this concern, future research should aim to examine the mechanisms by which both GNG training and SST training influence behavior. Namely, the conflicting findings of Bowley et al. (2013) and Houben et al. (2012) need to be consolidated. While Houben et al. (2012) demonstrated that differences in IAT performance mediated the influence of training on alcohol consumption, Bowley et al. (2013) were unable to replicate this effect, questioning whether GNG training does in fact influence evaluations of health-related stimuli, and whether this is responsible for differences in health behavior.

Additionally, the mechanism by which SST training influences behavior has received limited attention. In one study, Nagy (2012) measured improvement in neutral SST performance after behavior-specific training, in order to determine whether training improved inhibitory control capacity. Results demonstrated that all conditions improved on this task, suggesting a practice effect. Future research should employ an alternative measure of inhibitory control, such as the Stroop task, in order to avoid potential confounds from practice effects due to task similarity.

Results of the meta-analysis appear to confirm the assumption that the inhibitory control training task needs to be behavior-specific in order to influence the targeted behavior. Overall, studies that included a neutral task did not produce substantial effect sizes. This implies that exercising inhibitory control in general is not enough to influence behavior. While inhibitory control may improve, behavior change may not occur because inhibitory control has not been directed toward a specific behavior. In order to confirm this, studies aiming to influence behavior through inhibitory control training should include both a behavior-specific and neutral training condition as well as an additional measure of inhibitory control. Behavior-specific training should result in improved performance on the additional
inhibitory measure, as well as improvement in behavior, whereas neutral training should only demonstrate improvement on the inhibitory control task.

**Length of training**

No studies have systematically examined whether the length of inhibitory control training influences the strength of behavioral outcomes. Current results indicate that longer training sessions did not produce larger effects. However, it is worth noting that many other factors within the included studies may have contributed to the unsubstantial effect. Studies with the longest training sessions tended to utilize neutral training tasks. An additional analysis was conducted to examine the influence of length of training on differences in behavioral outcomes only within studies that utilized a behavior-specific task and measured behavior immediately, yet no moderating effect was detected. Future studies should systematically vary the number of trials and number of sessions in order to determine if more training results in greater benefits to behavioral outcomes.

**Behavior**

It appears that behaviors, such as unhealthy eating and alcohol consumption, are more suited to inhibitory control training than compulsive gambling. However, this may be confounded by the fact that all studies on compulsive gambling utilized a neutral training task. As such, future research aiming to change compulsive gambling behavior should develop and utilize a behavior-specific task. Alternatively, it may be the case that the samples used in compulsive gambling studies were not suitable targets for inhibitory control training as they were community volunteers who were not necessarily compulsive gamblers, or did not necessarily have a preference for compulsive gambling. Conversely, the majority of the remaining studies recruited a sample that had a preference for the target behavior. Hence, these samples had difficulty regulating that behavior and would therefore benefit from training. For example, Bowley et al. (2013) aimed to change drinking behavior through training on a GNG
that included beer stimuli and therefore recruited those who had a preference for beer, and regularly drank this particular alcohol. Future studies with the aim of reducing gambling behavior through inhibitory control training should target individuals with compulsive gambling tendencies.

**Stability of effect**

Results appear to indicate that differences in behavior between those who received inhibitory control training, and those who received some other form of training, are strongest when measured immediately. Specifically, when the effect of immediately administered objective measures of behavior was compared to objective measures administered post-training; it was revealed that the latter effect was not significant. Additionally, while non-objective measures that were administered post-training appear to produce small-to-medium effects, this may be due to the method of measurement. Namely, self-report measures such as the Timeline Follow-back questionnaire (Sobell & Sobell, 1992), may be subject to reporting bias and thus produce an inflated effect size. While Verbruggen et al. (2013) attempted to systematically demonstrate that the effect of training does not persist over time, this study employed a neutral SST. The results of this meta-analysis suggest that training using a neutral inhibitory control task is not as effective as a training using a behavior-specific inhibitory control task. Therefore, it is recommended that future research systematically examines whether the effects of training with a behavior-specific task persist over time.

**Strengths and limitations**

This is the first study to systematically synthesize the literature on inhibitory control training and behavioral outcomes. A strength of the current analysis was the extensive exploration of moderator effects to determine the source of inconsistencies in effect sizes. Additionally, the broad search strategy and inclusion of unpublished works ensured that the overall effect size was not inflated due to significant effects being more likely to be published. However, the
present analysis included effect sizes that were based on relatively small samples of studies, which may have inflated the overall effect size. Therefore, caution needs to be exercised when interpreting some of the reported effects.

In addition, the present analysis did not include behavioral outcomes such as differences in brain activation as demonstrated by EEG, such as that presenting in (Bowley et al., 2013). While the primary aim of the present analysis was to examine the effect of training on behavioral outcomes, such as alcohol consumption and eating behavior, it may be worthwhile to systematically review the influence of inhibitory control training on neurophysiological outcomes and brain plasticity, particularly to further elucidate the mechanisms by which training may influence behavior (for a narrative review, see: Spierer et al., 2013). While some studies did attempt to examine potential mechanisms by which training improved behavior (Bowley et al., 2013; Houben et al., 2012; Houben et al., 2011; Nagy, 2012), there were too few to conduct an analysis of the size of the effect of training. Finally, few studies included a pre-post design to assess change in behavior; as such, the results of the present meta-analysis primarily reflect differences in behavior between conditions. To address this concern, future studies should attempt to include measures that allow for pre- and post-intervention assessment of behavioral outcomes.

Conclusions
The present meta-analysis provides evidence that inhibitory control training results in differences in behavioral outcomes. Evidence indicates that both the GNG and the SST are effective at reducing health-compromising behaviors such as alcohol consumption and unhealthy eating. However, these tasks need to be tailored to the target behavior in order to be successful. While it appears that length of training does not influence the size of the effect, and that the effects do not persist long after the training session, these elements need to be systematically examined in order to reach any firm conclusions. Determining the optimal
length of training, and whether these effects transfer to everyday behavior, would provide the
cbasis for cost-effective and efficacious methods to promote health behavior.
References


